

Scripps Institution of Oceanography, University of California San Diego

How climate model complexity influences sea ice stability

Till J.W. Wagner and Ian Eisenman

EGU General Assembly - 15 April 2015

Are we facing an Arctic sea ice ‘tipping point’ ?

Idealized Models: **Yes** (potentially)

GCMs: **No** (most probably)

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1. Why do low and high order models disagree ?
2. What does that mean for the real world?

What are
these
idealized
models ?

Energy
Balance
Models
(EBMs)

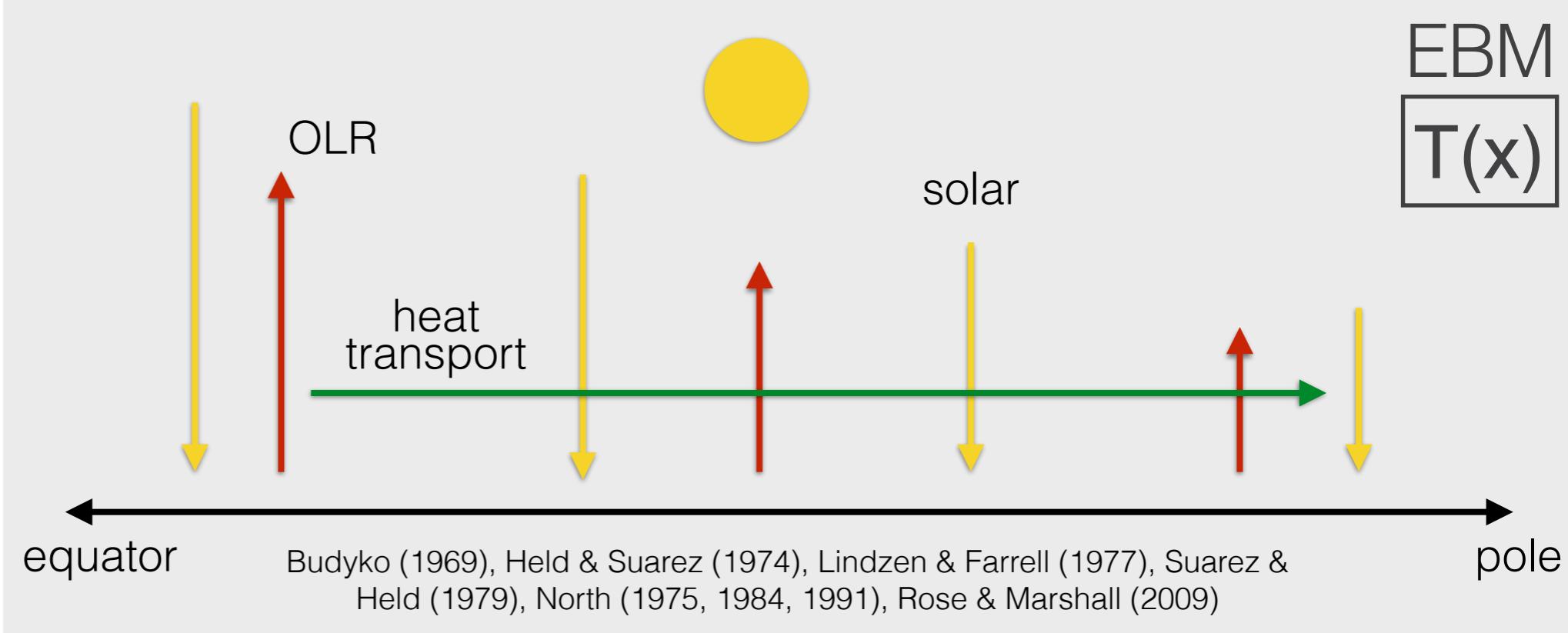
Single
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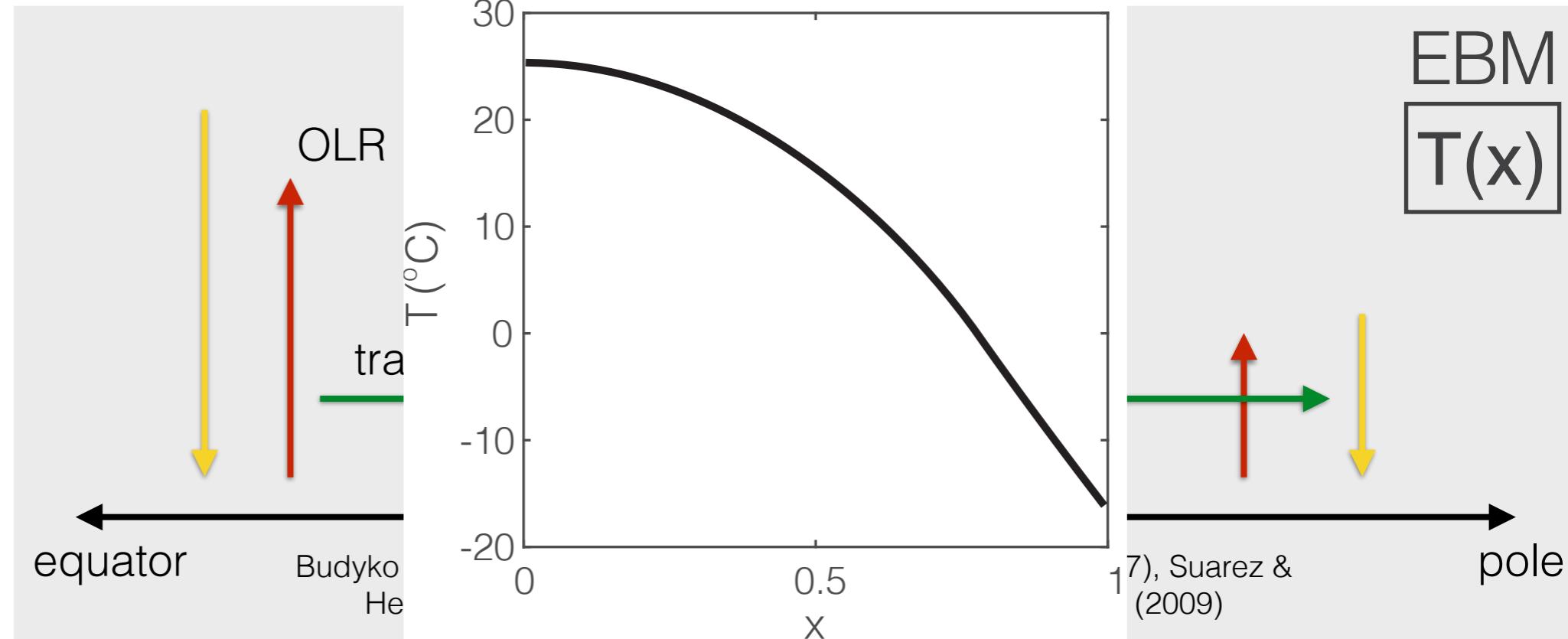
EBM
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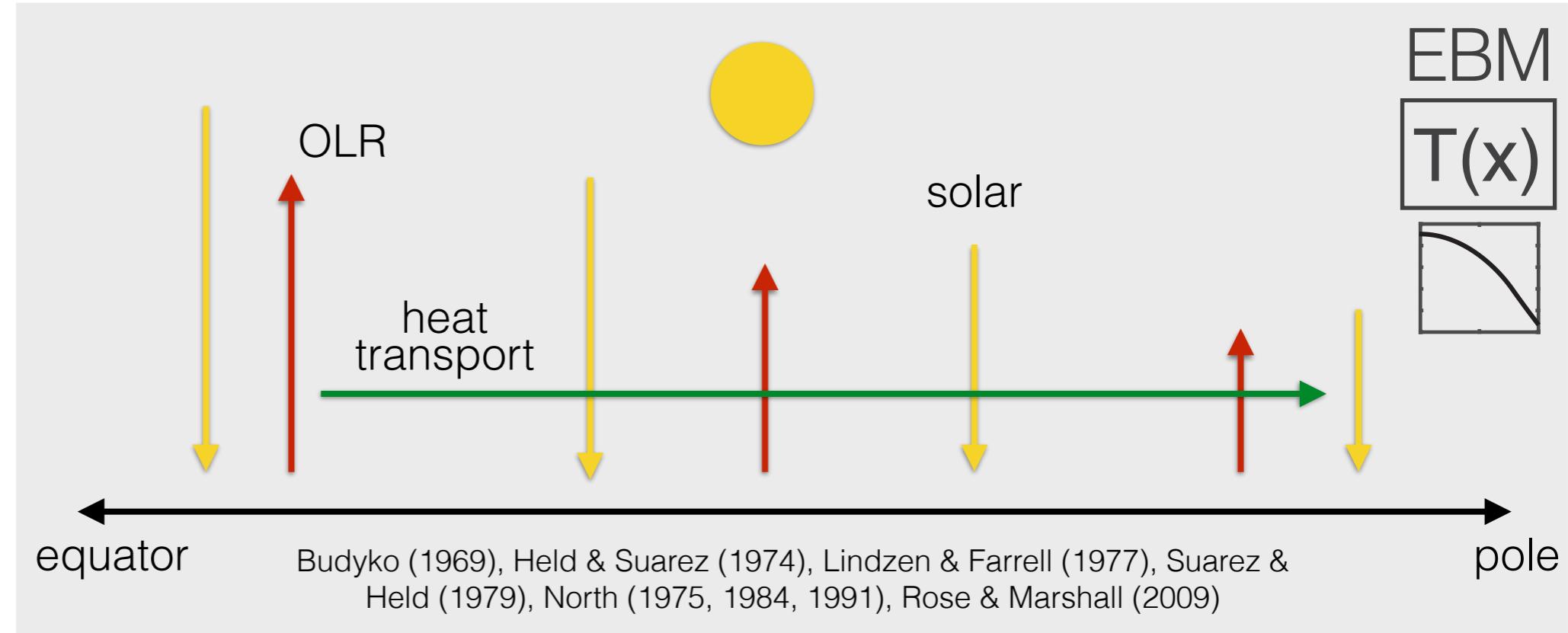
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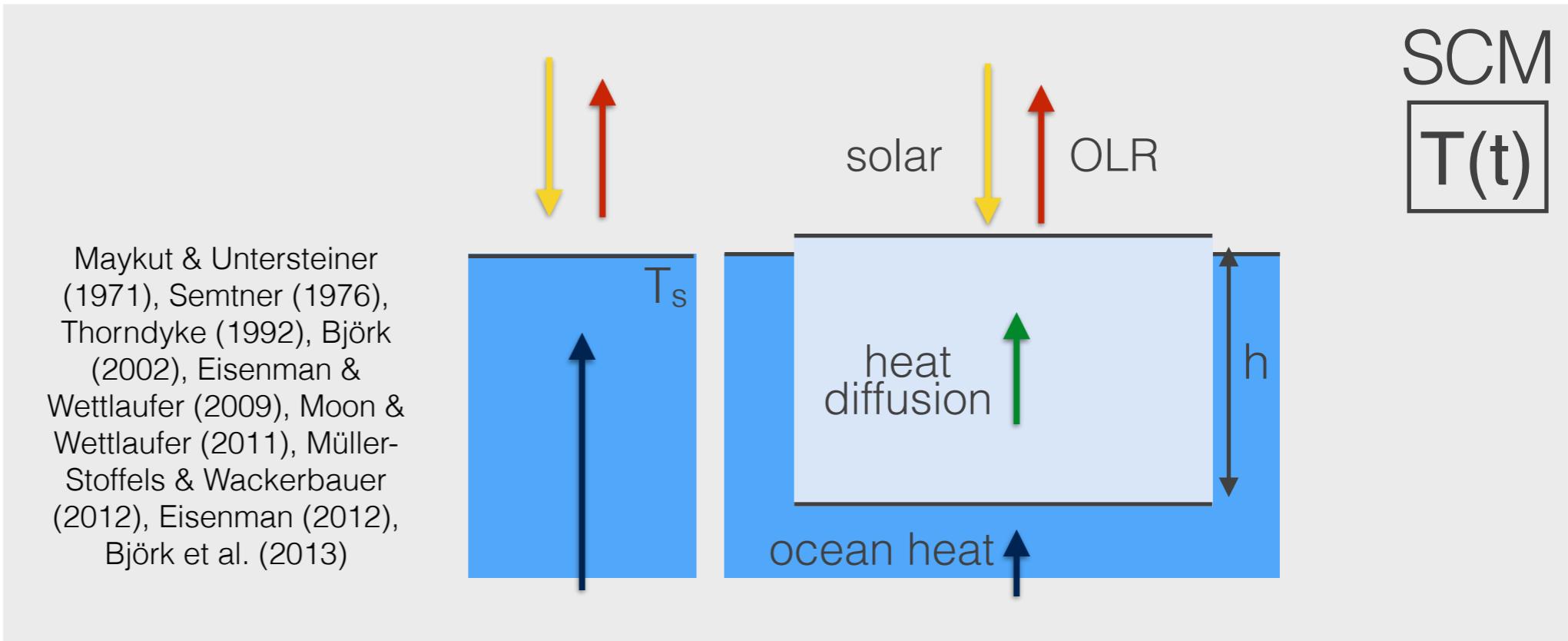
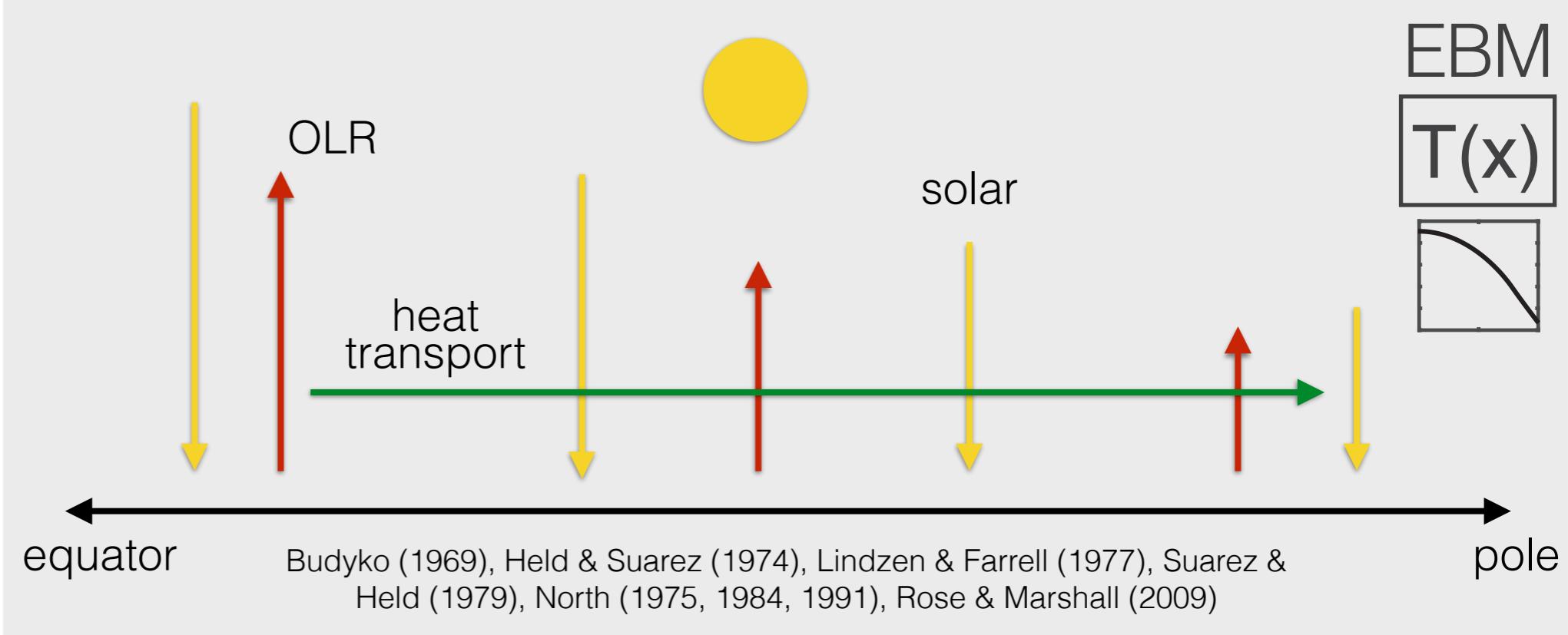
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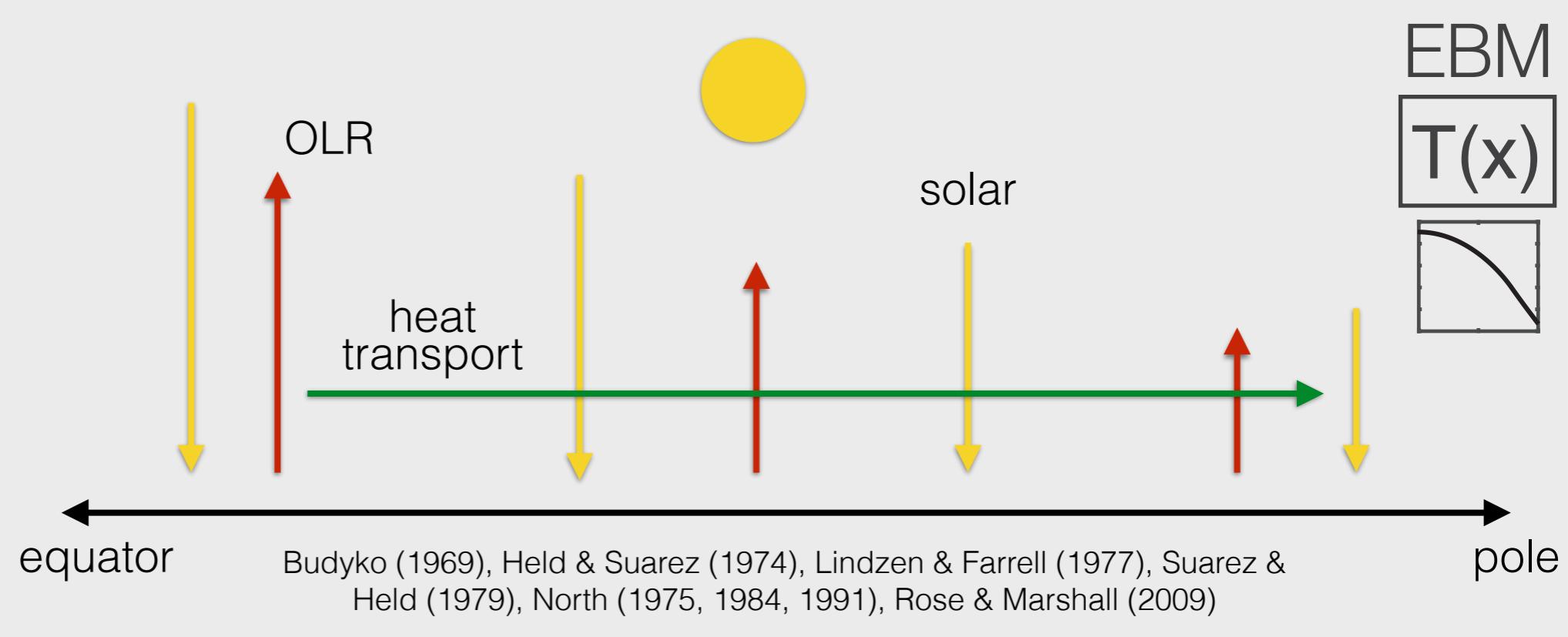
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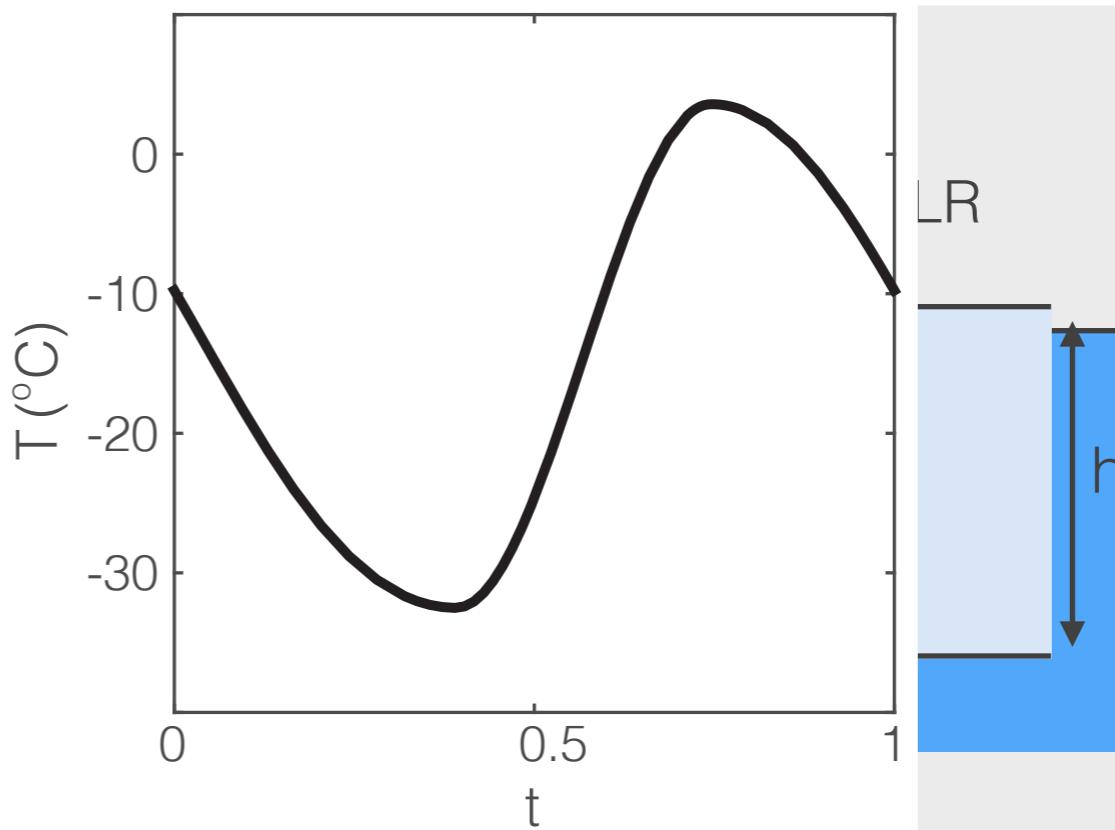
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Maykut & Untersteiner (1971), Semtner (1976), Thorndike (1992), Björk (2002), Eisenman & Wettlaufer (2009), Moon & Wettlaufer (2011), Müller-Stoffels & Wackerbauer (2012), Eisenman (2012), Björk et al. (2013)



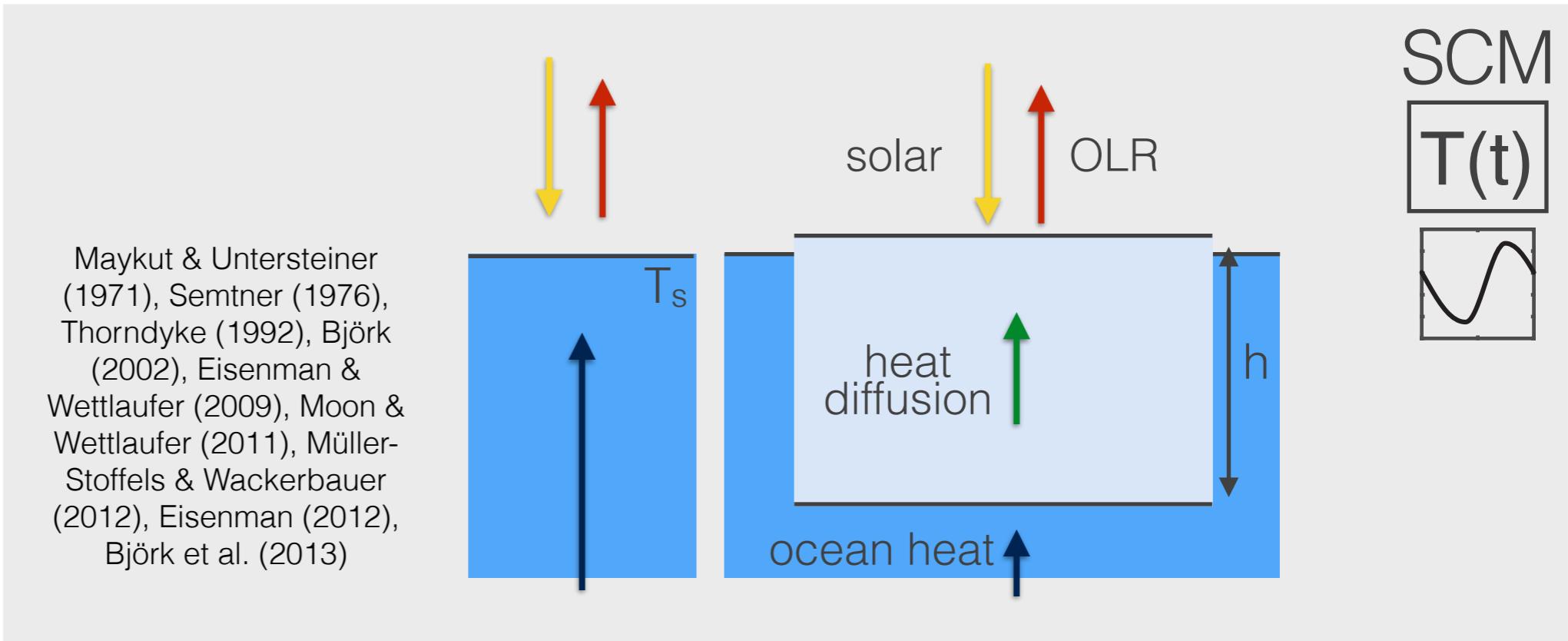
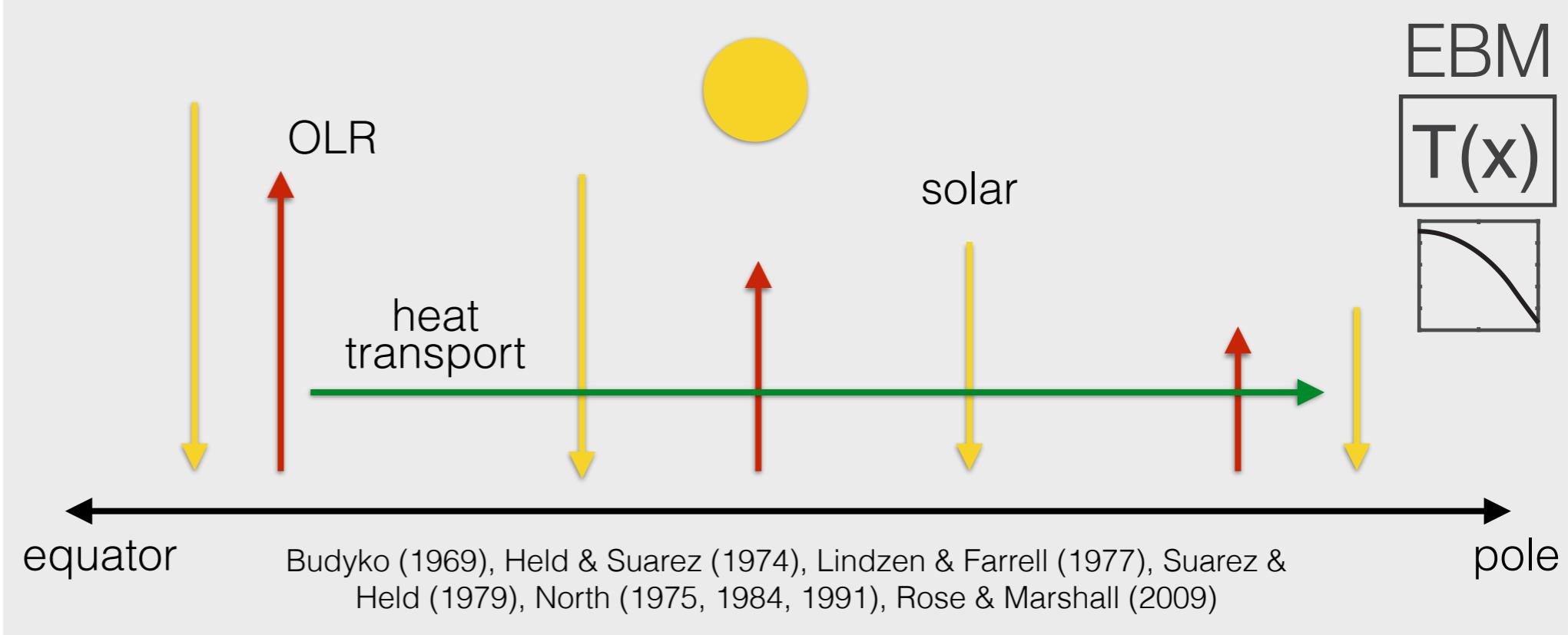
EBM
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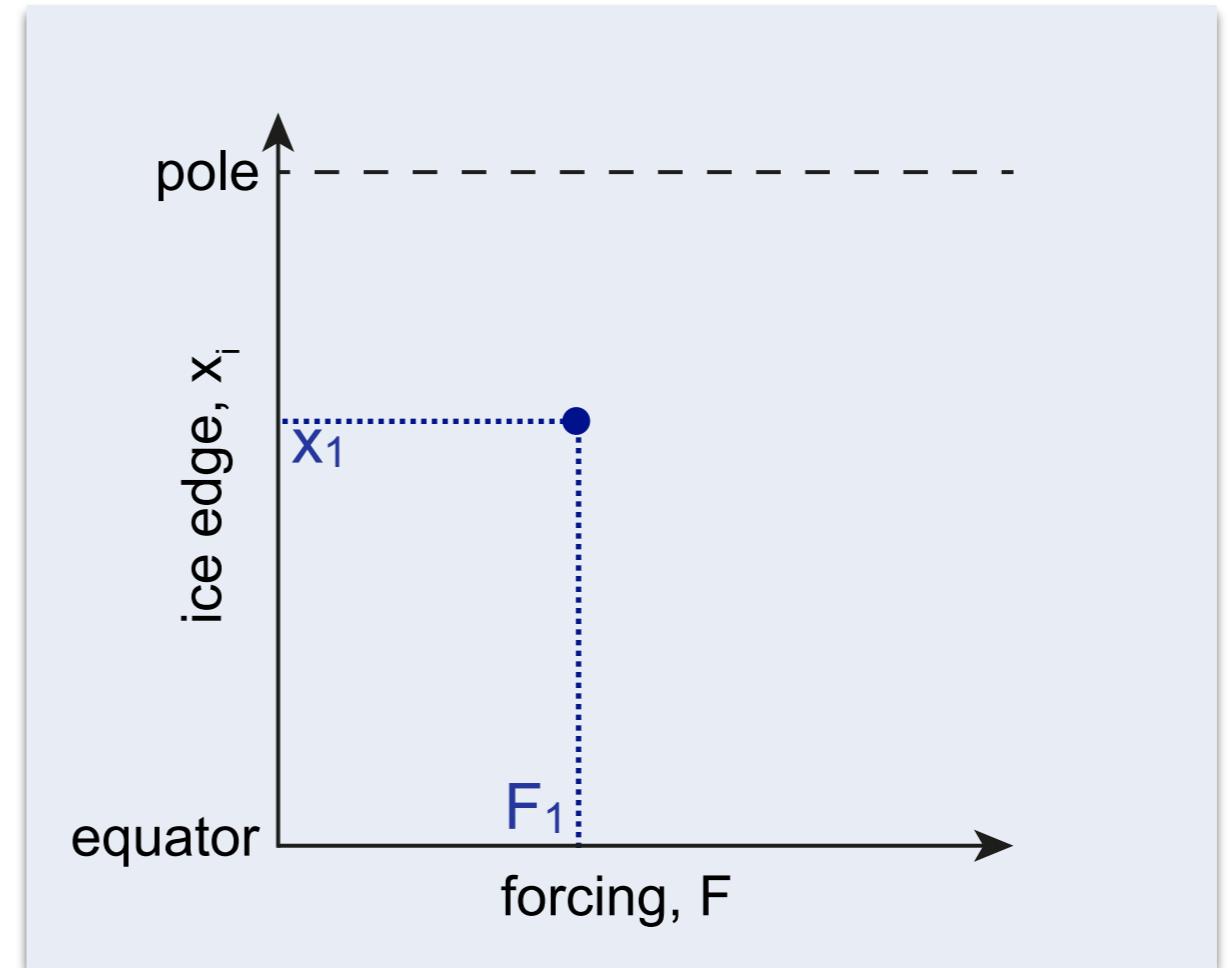
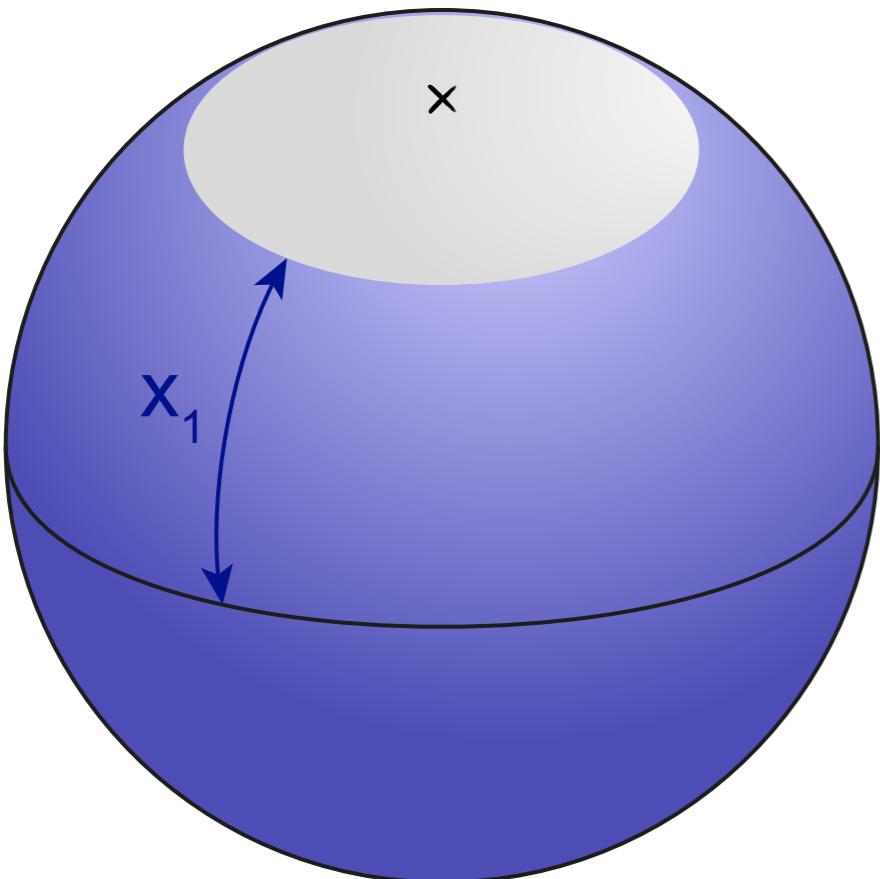
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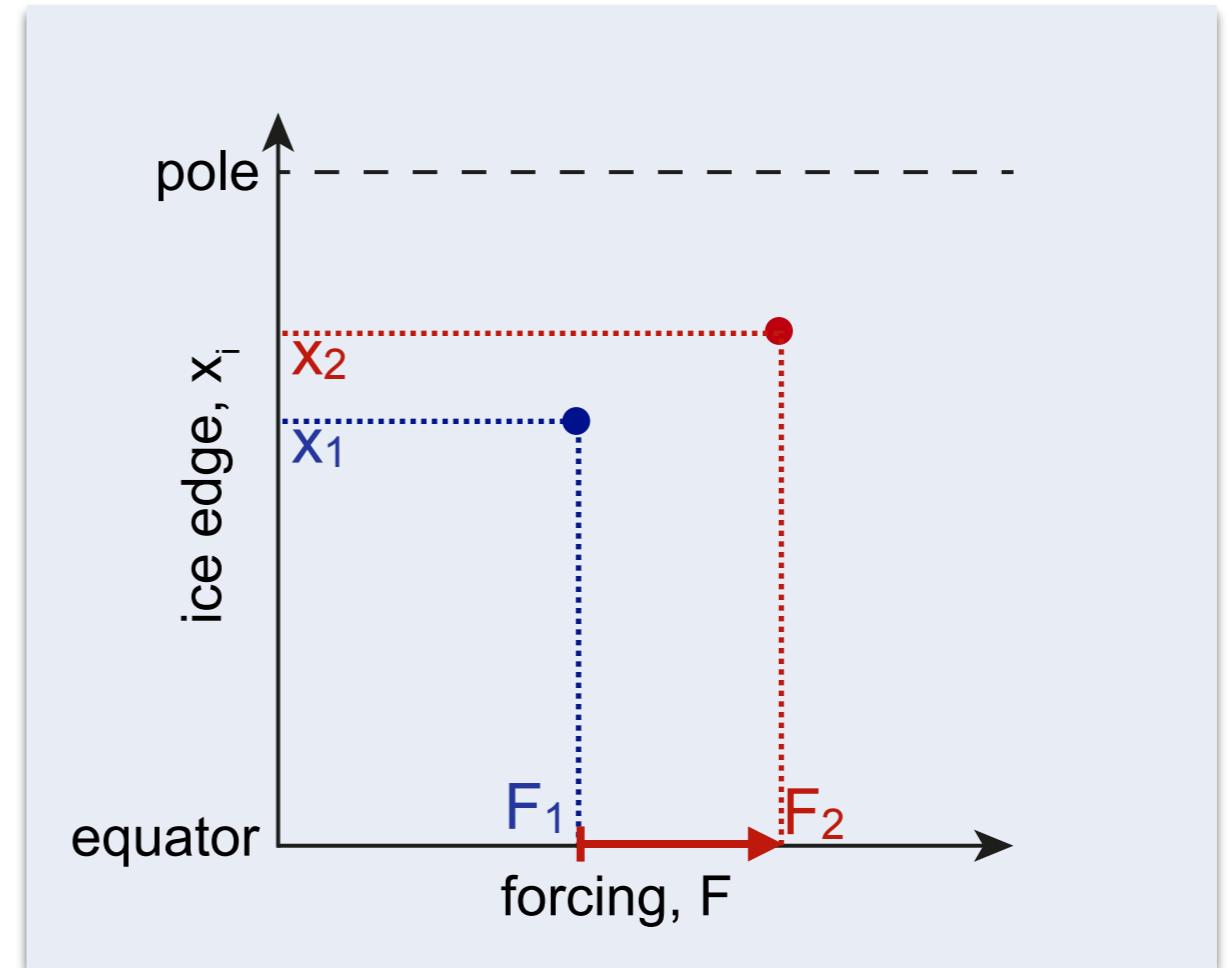
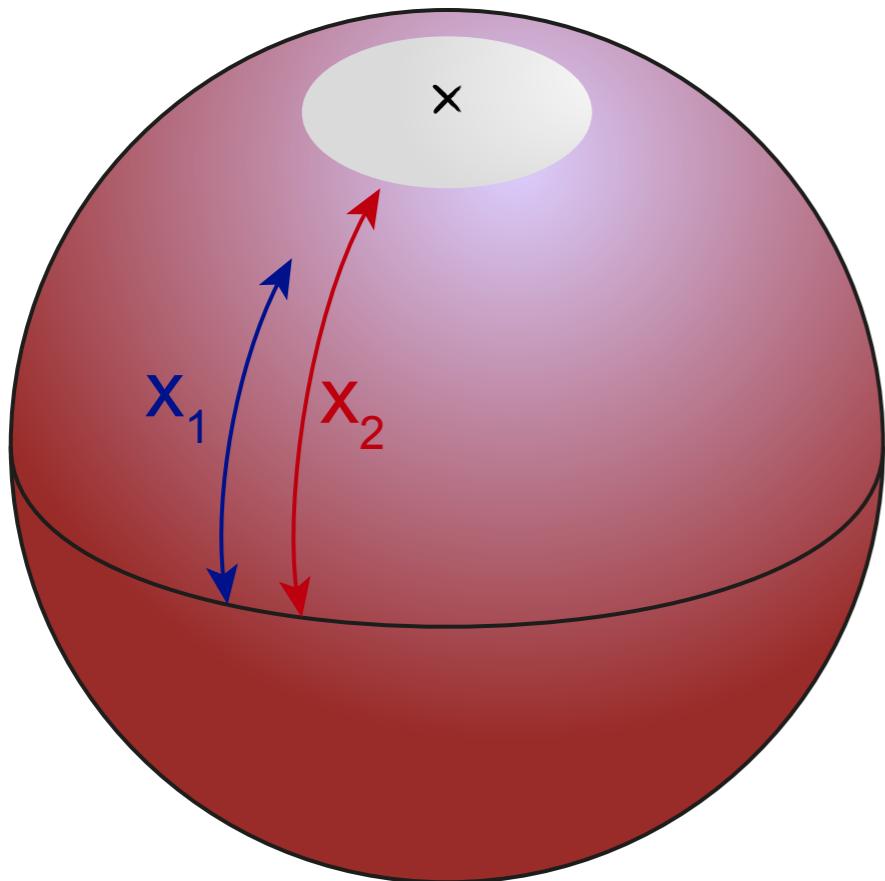
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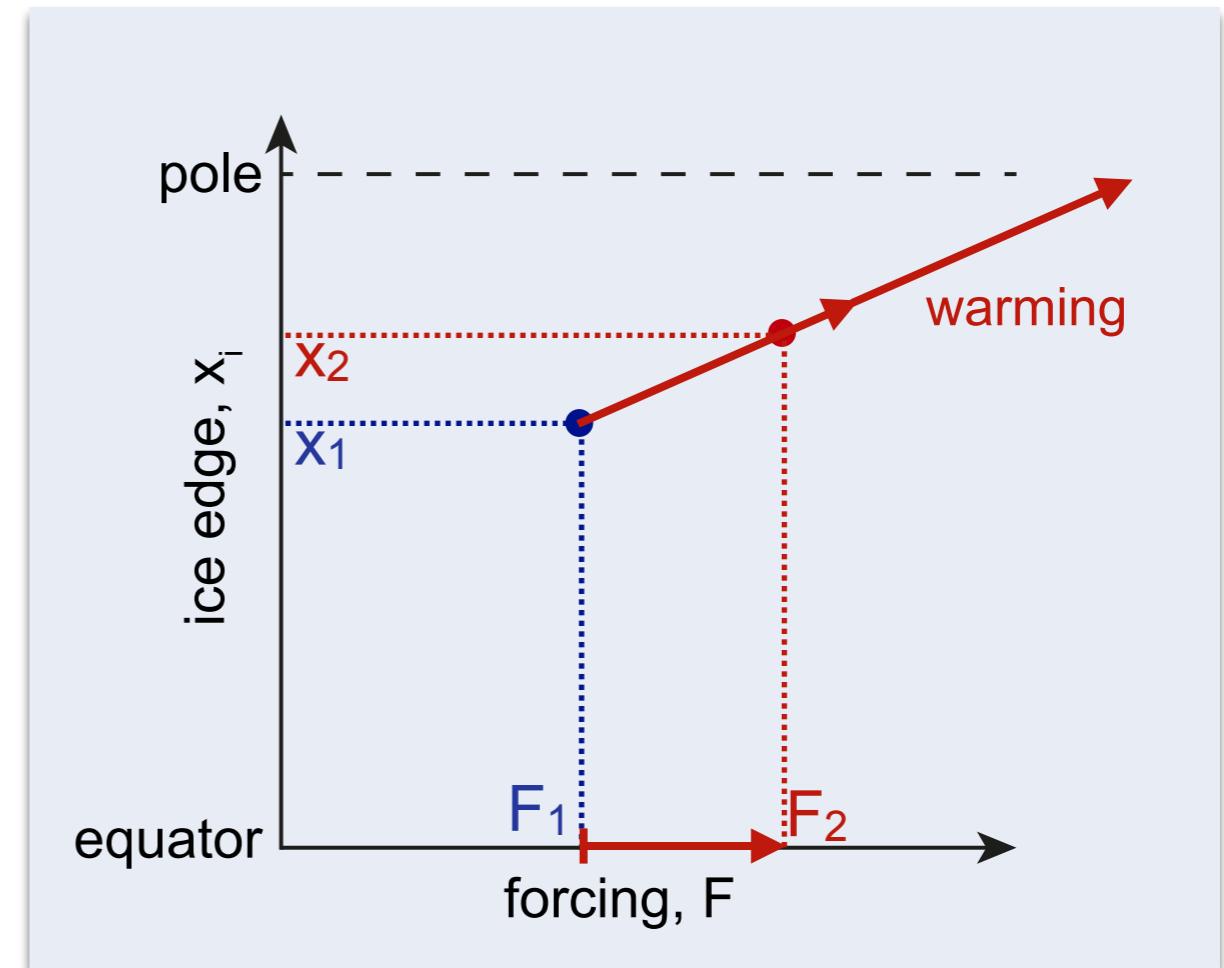
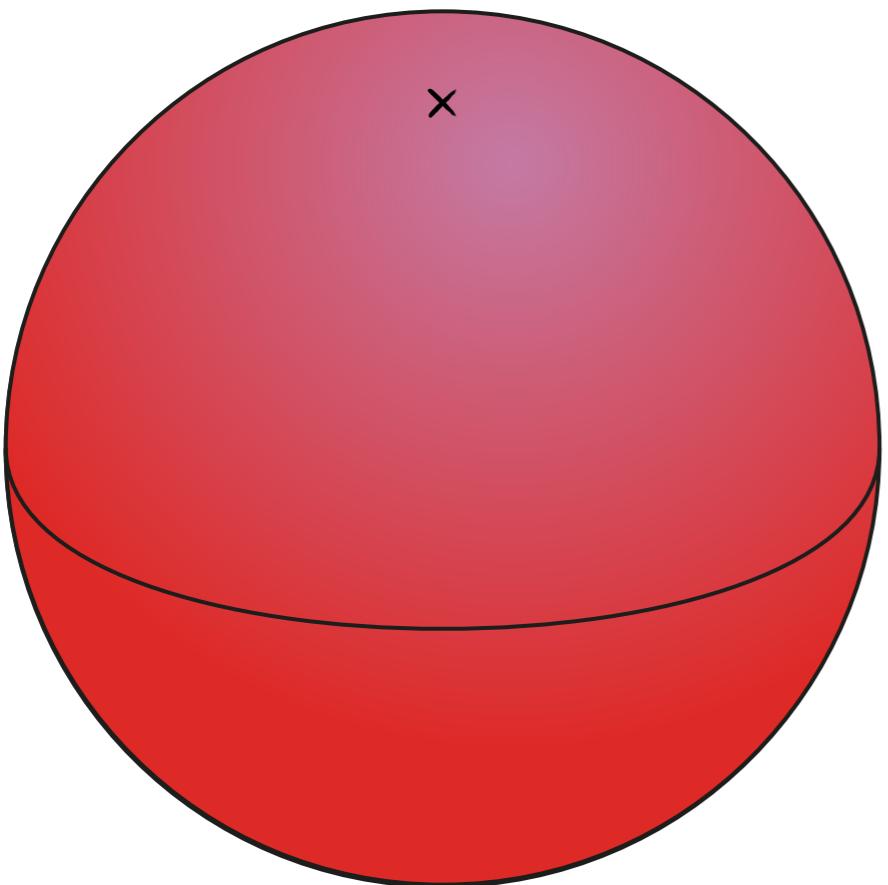
What do we mean by instability (or ‘tipping point’)?



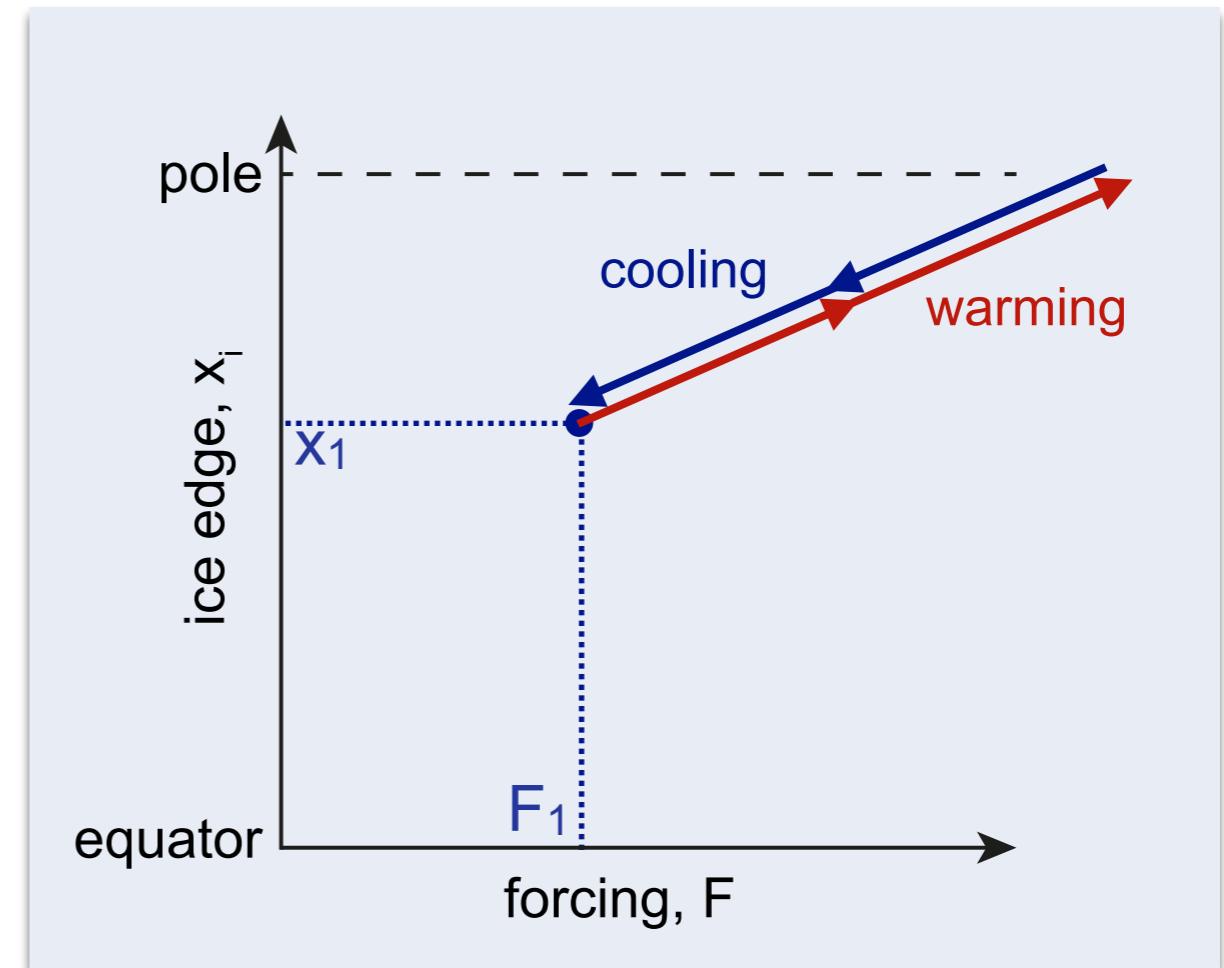
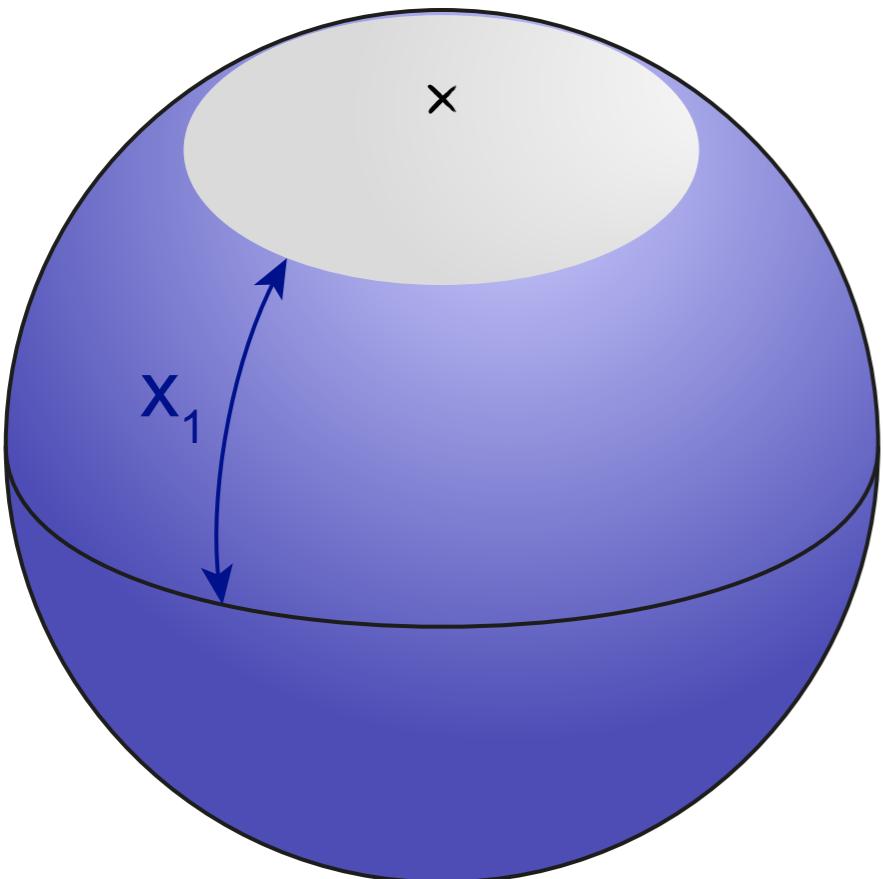
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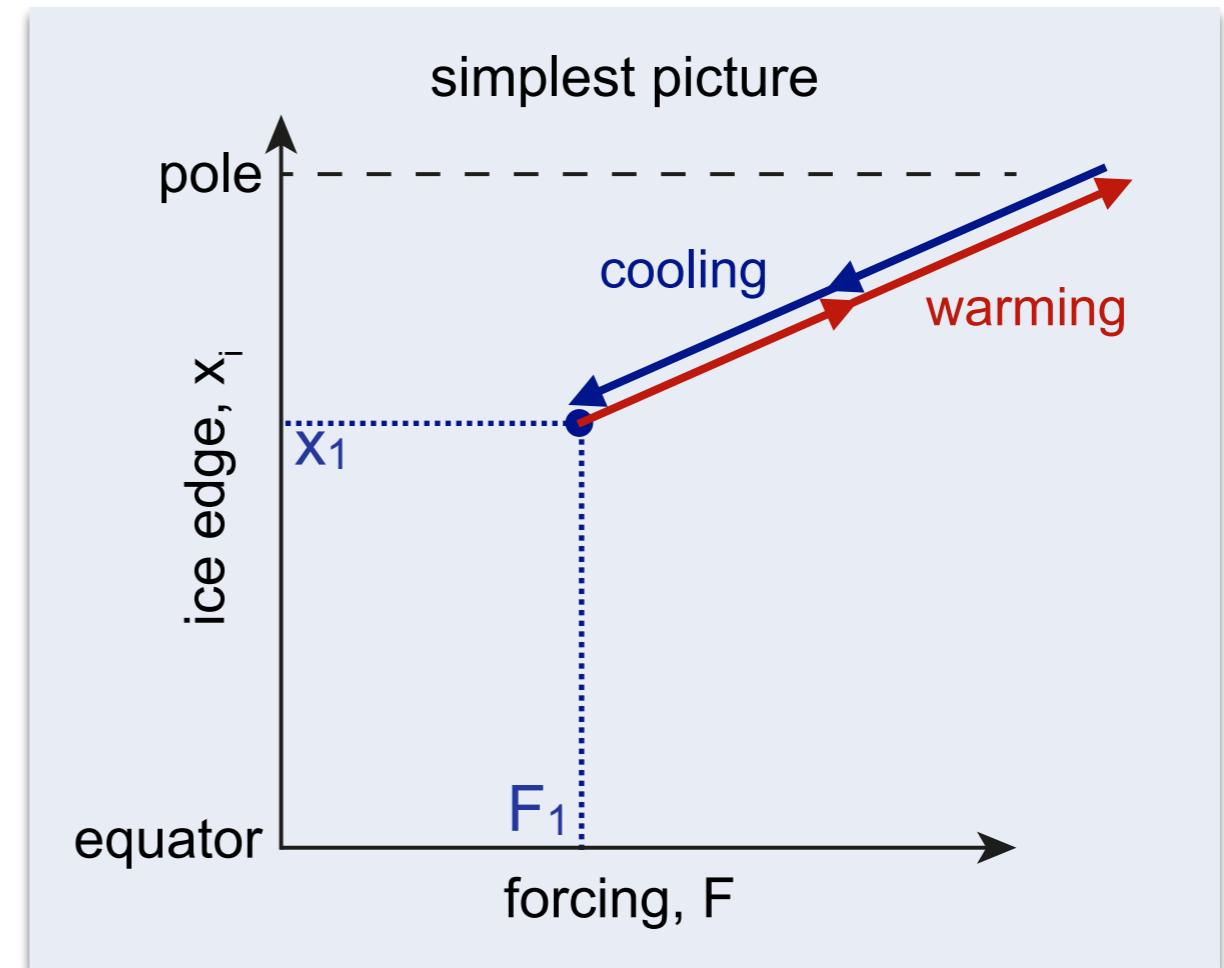
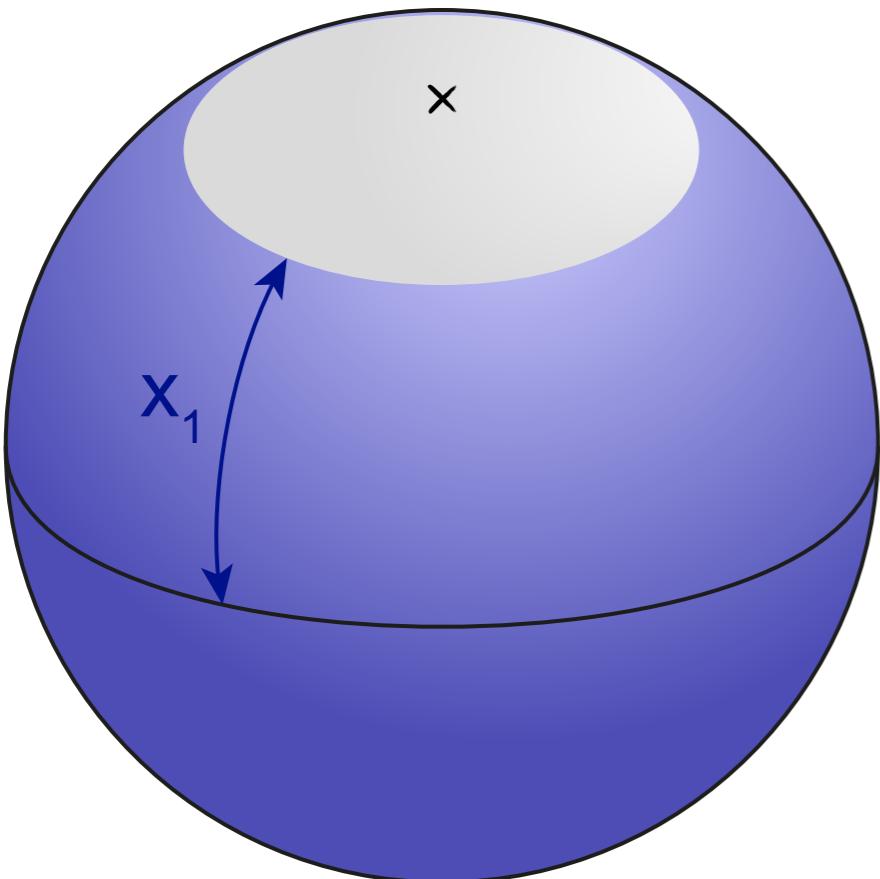
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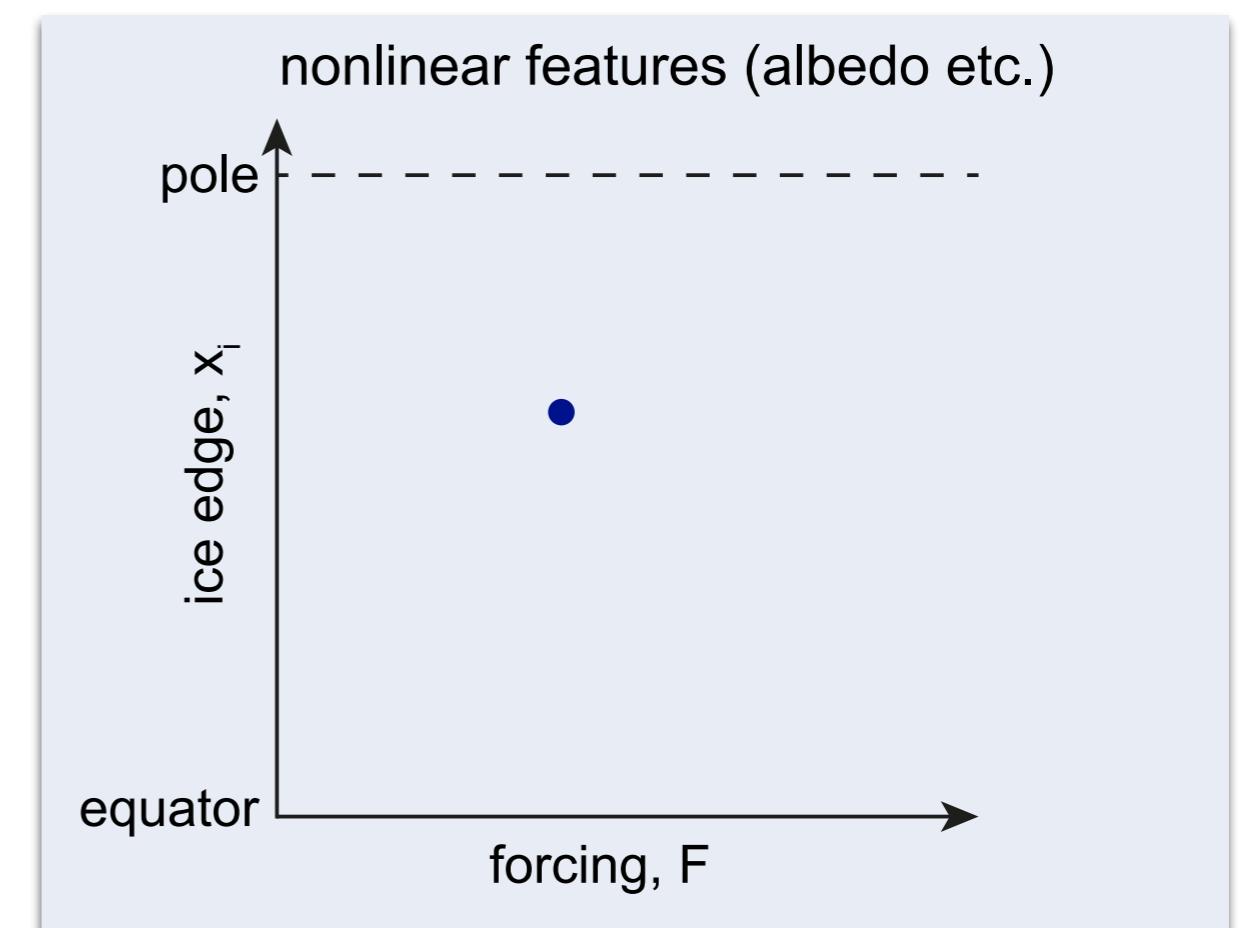
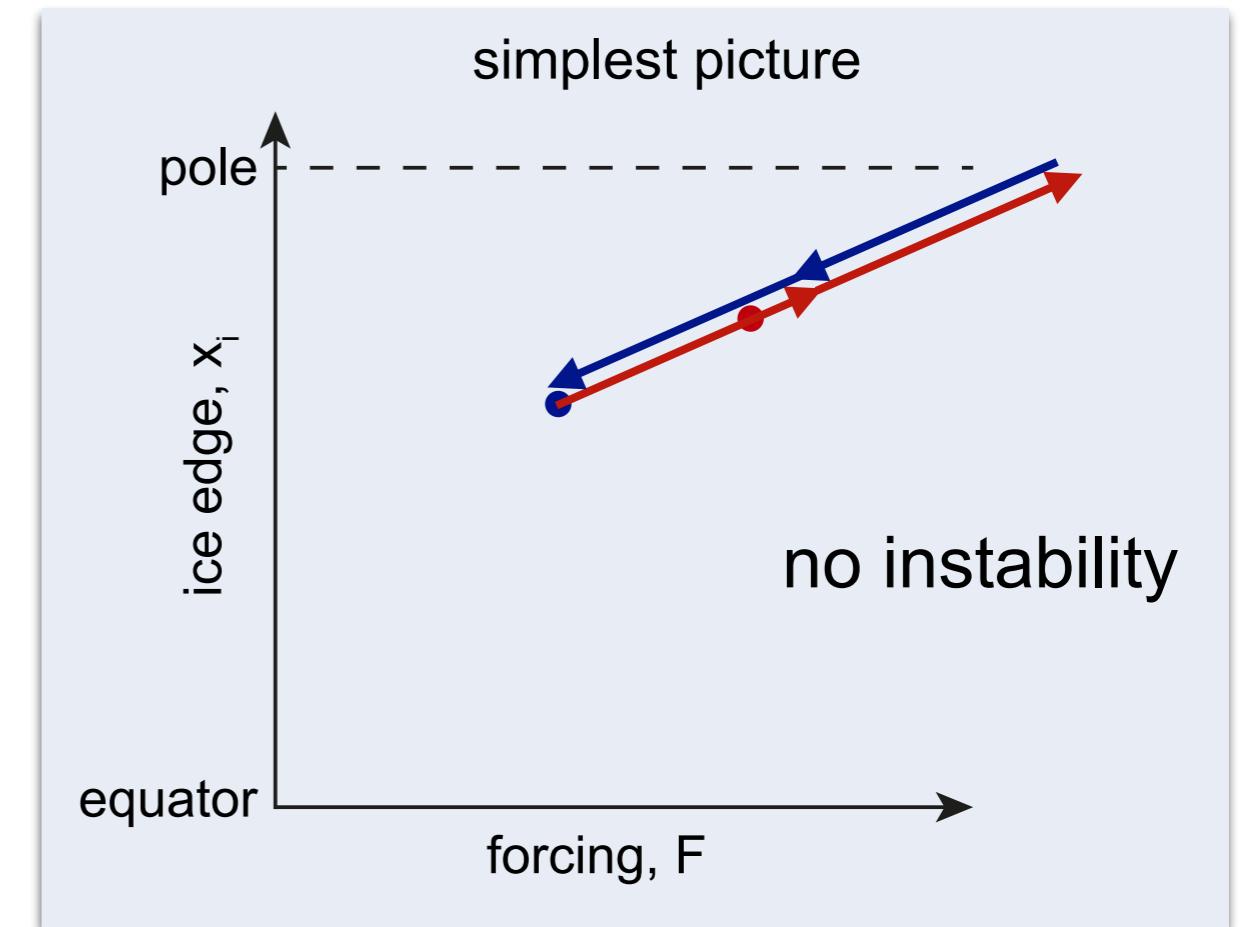
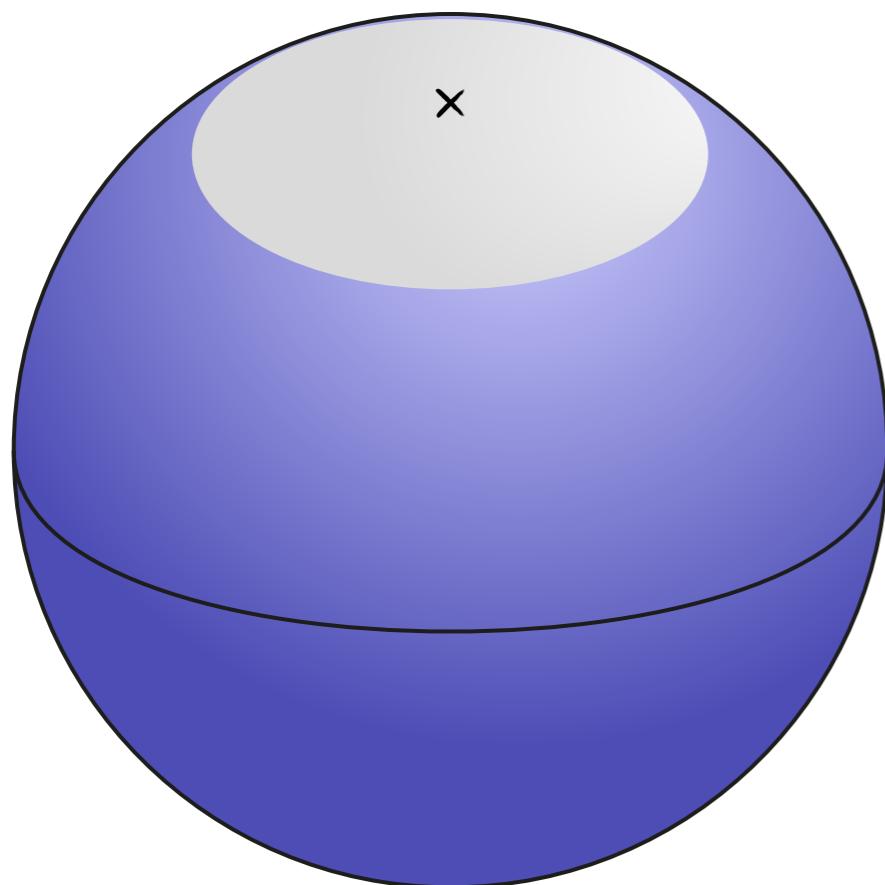


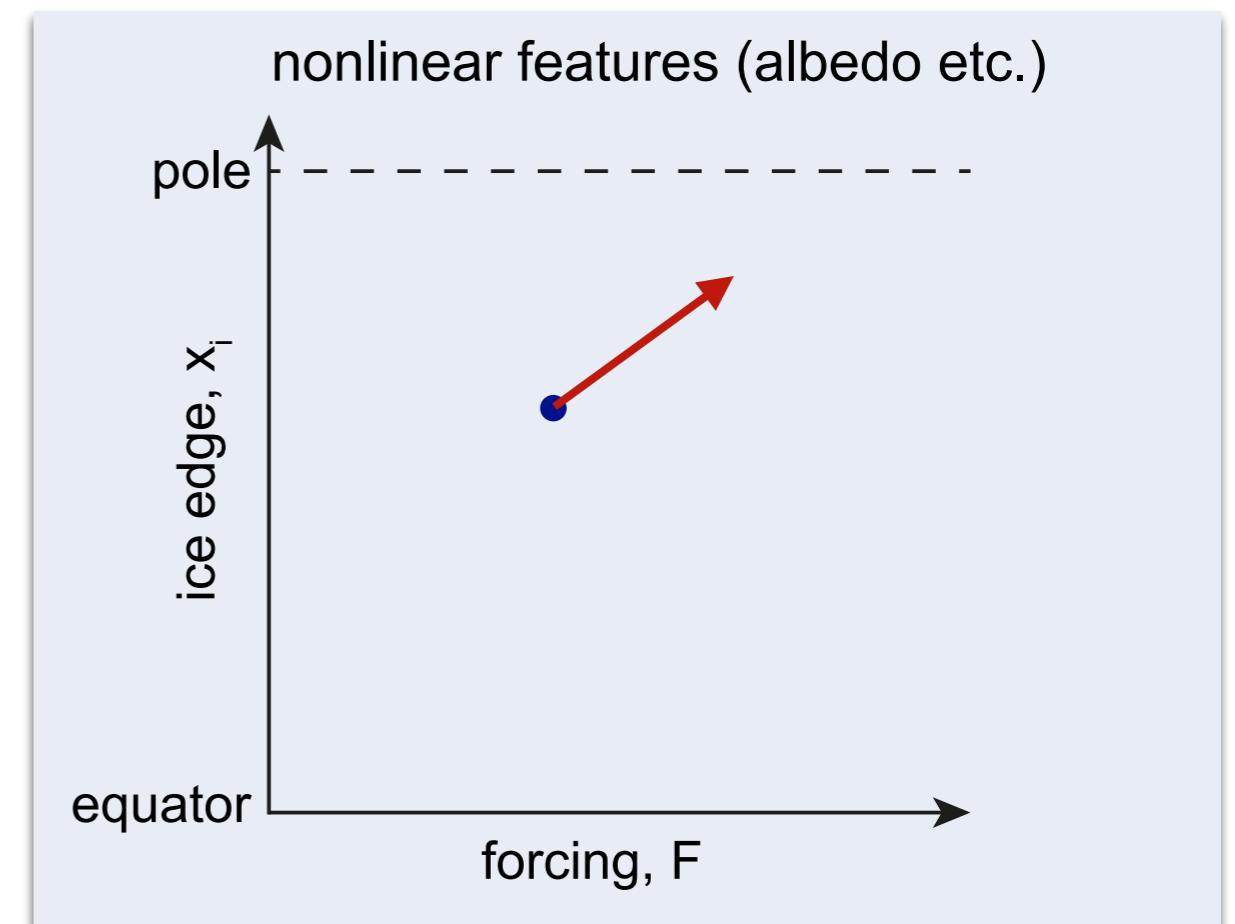
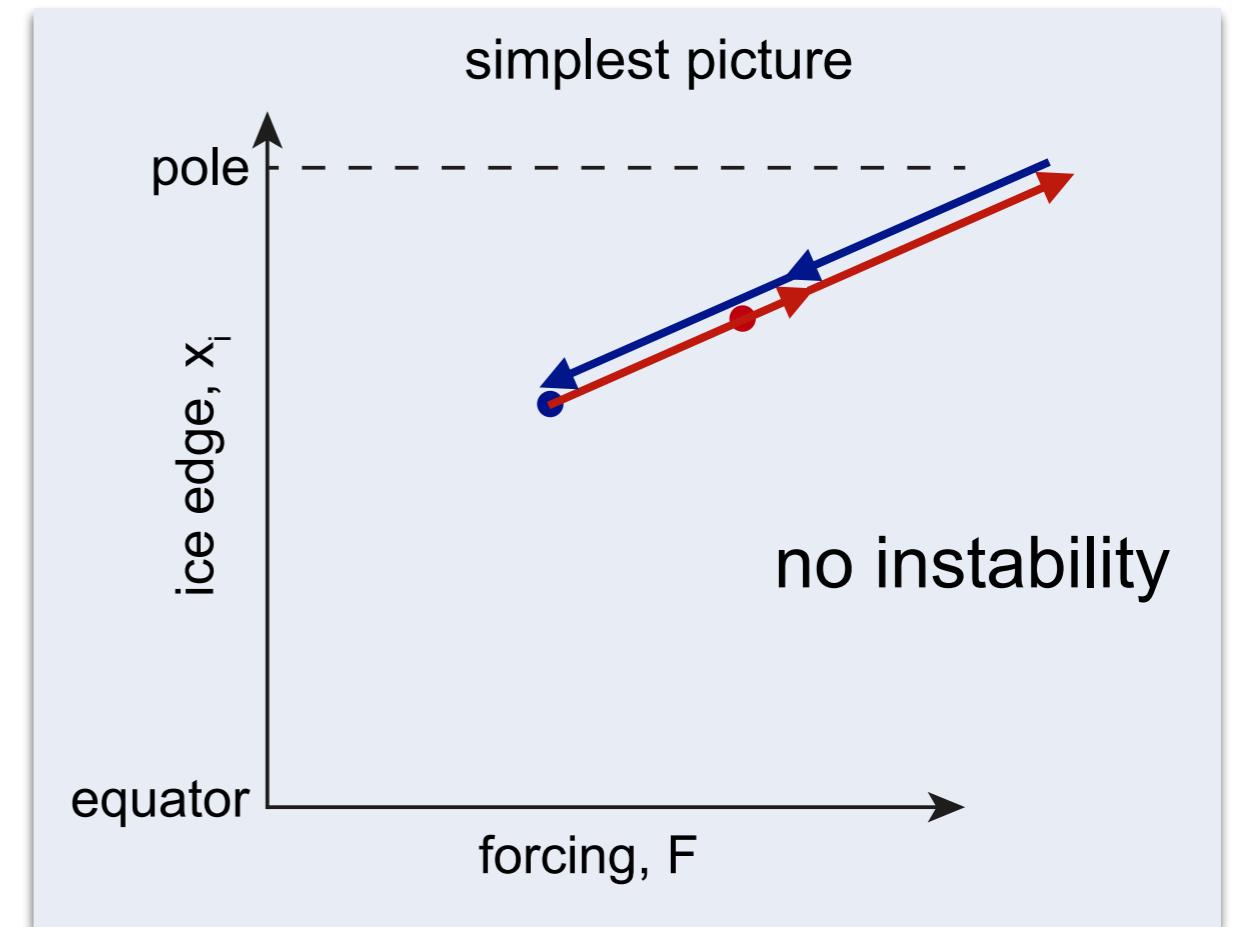
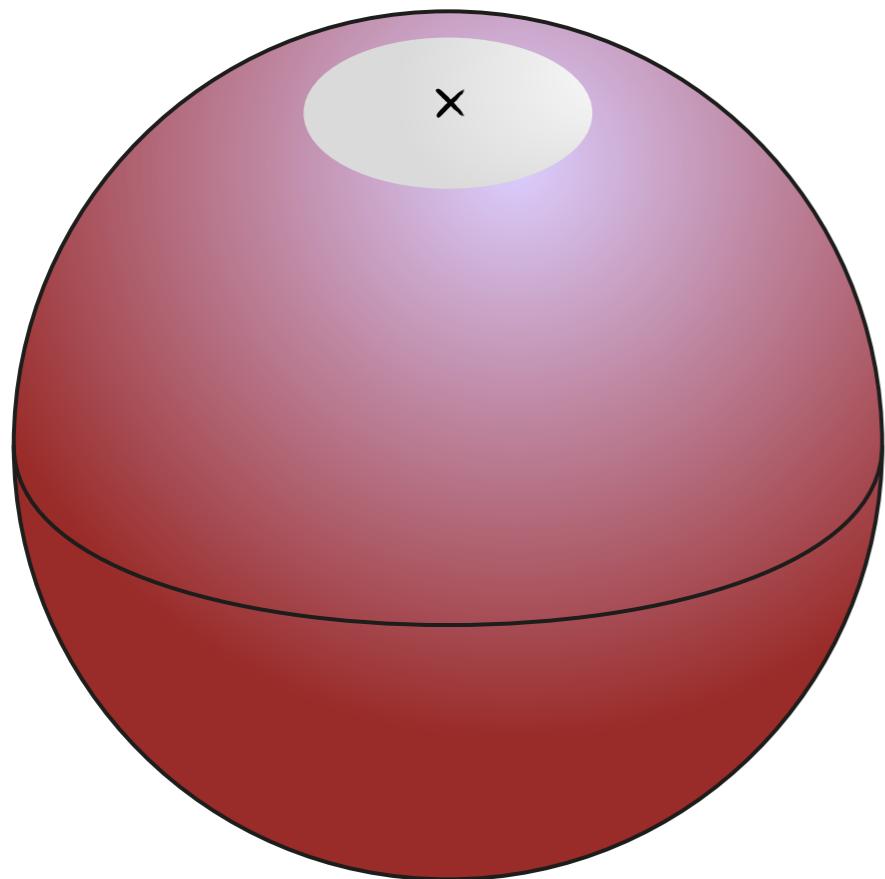
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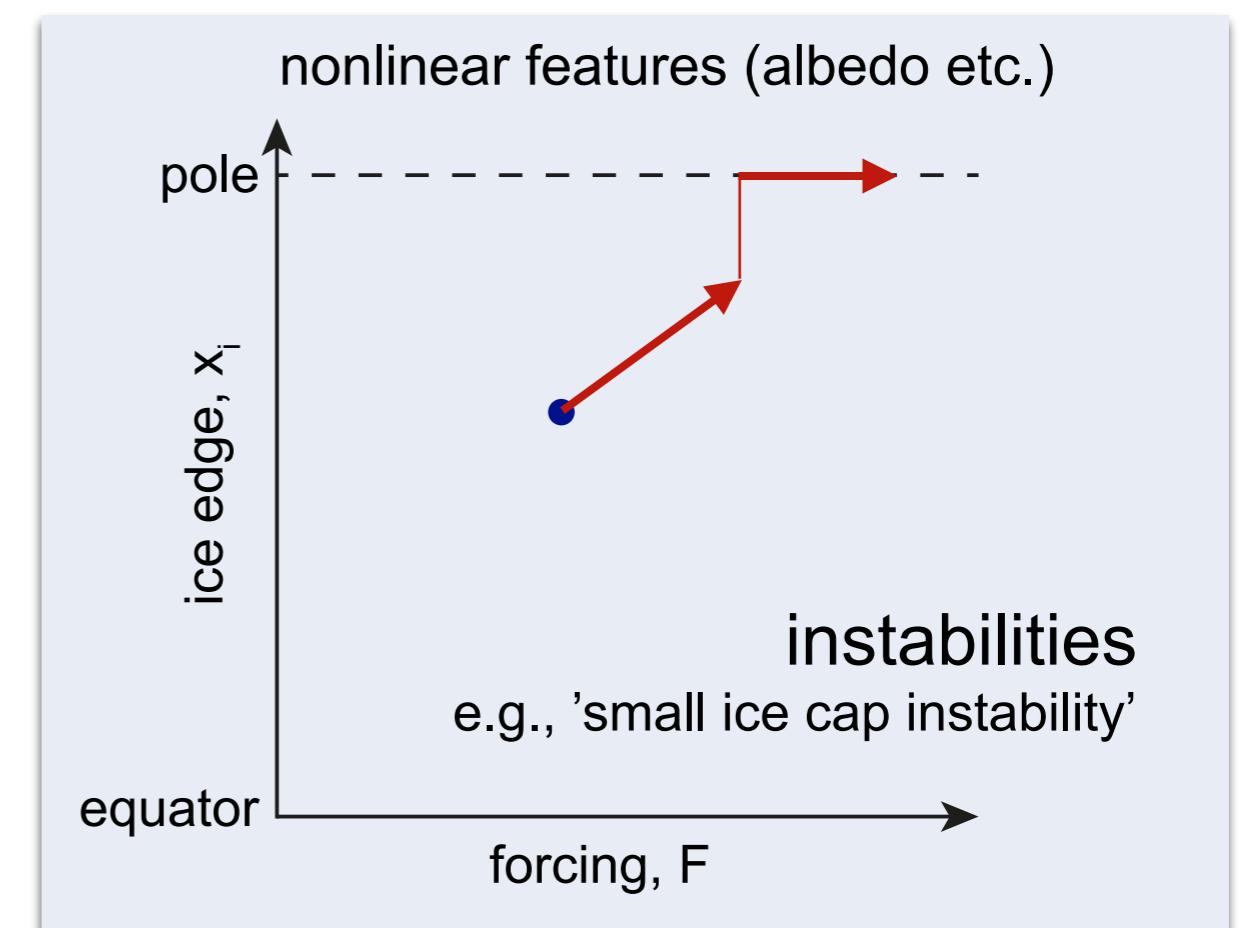
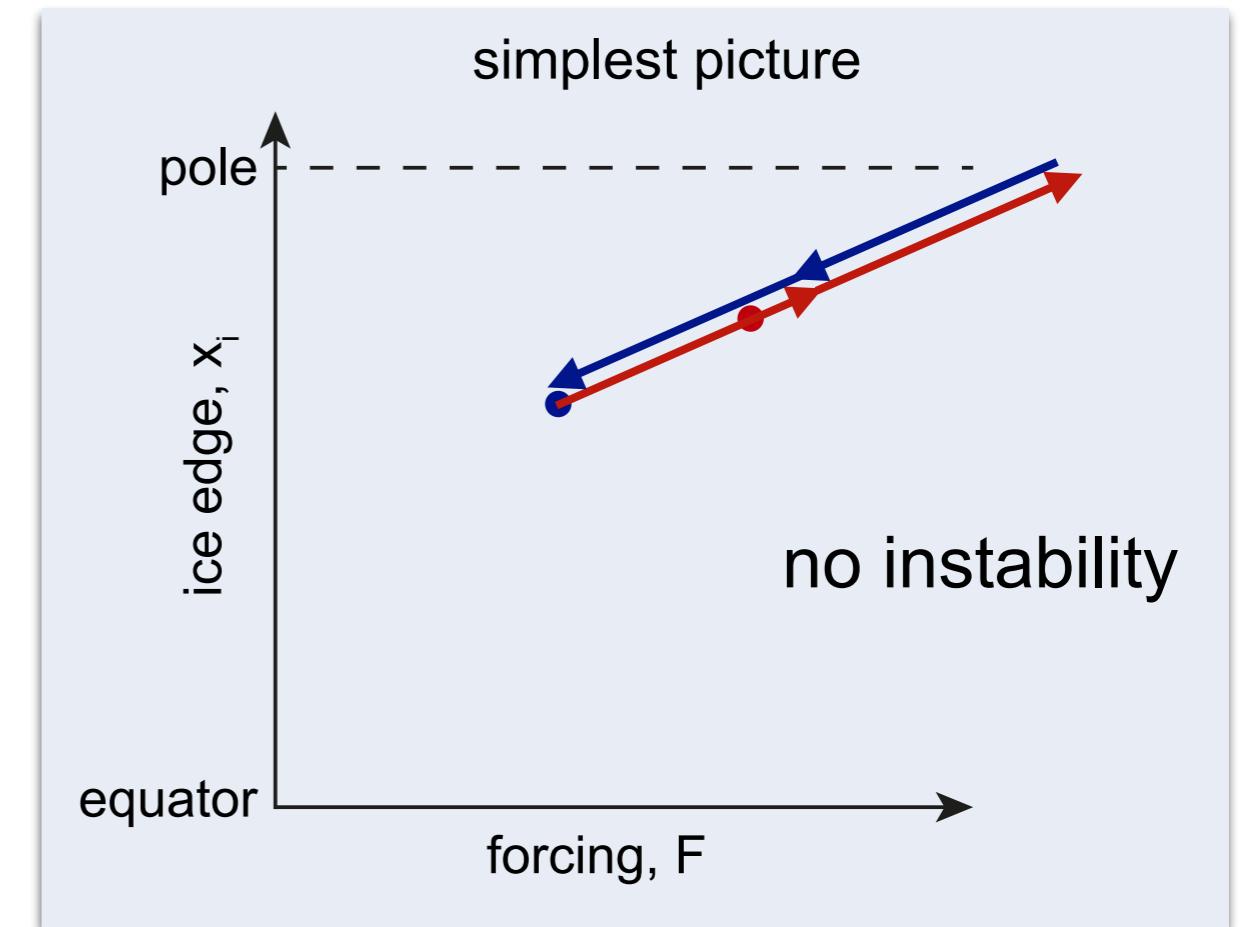
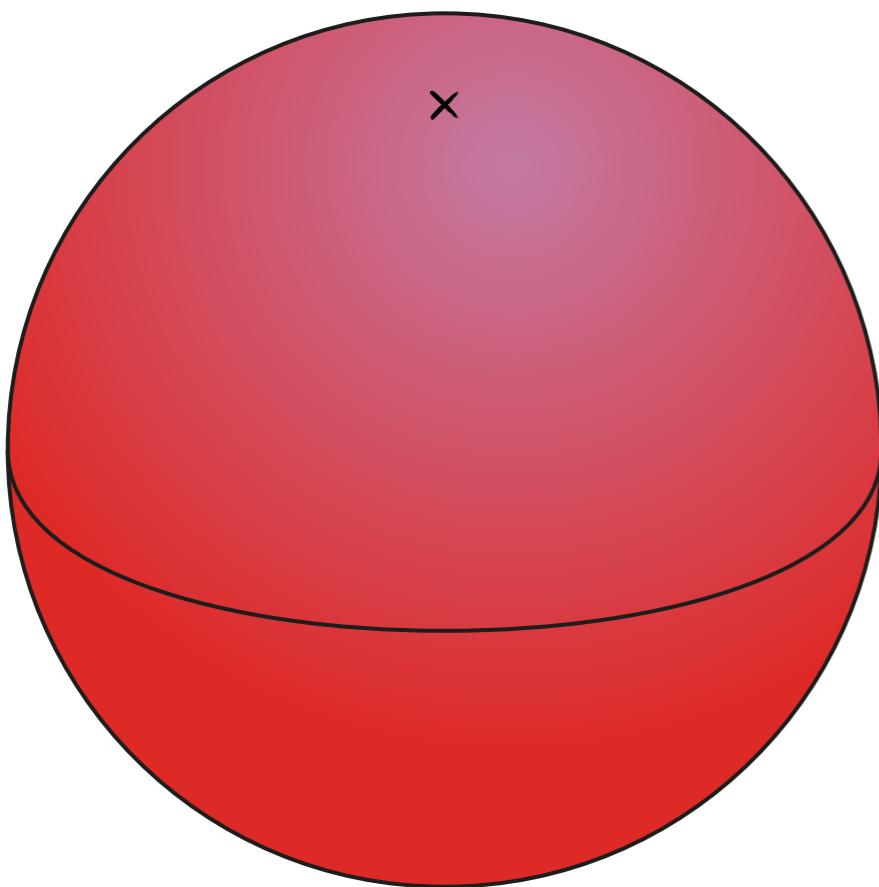


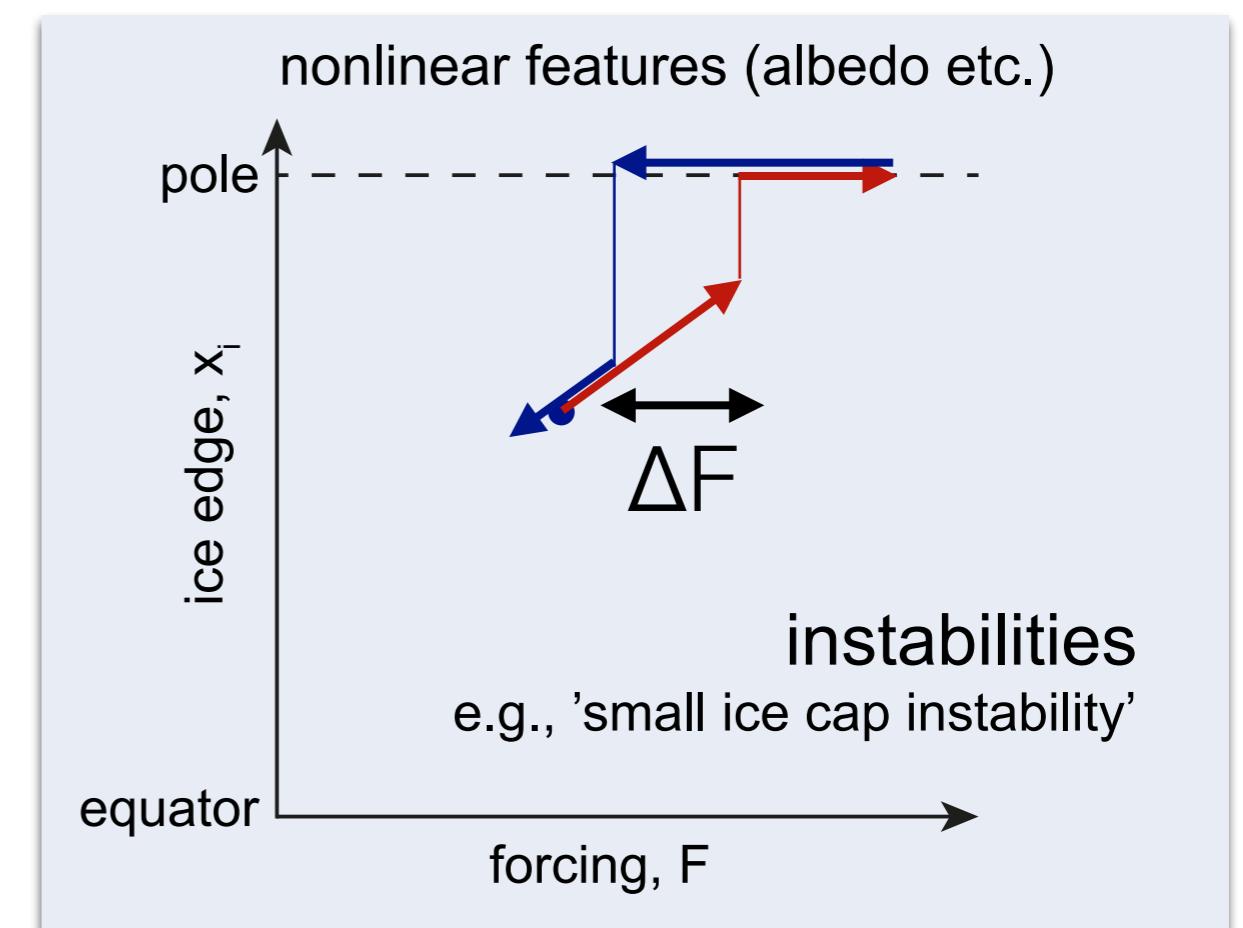
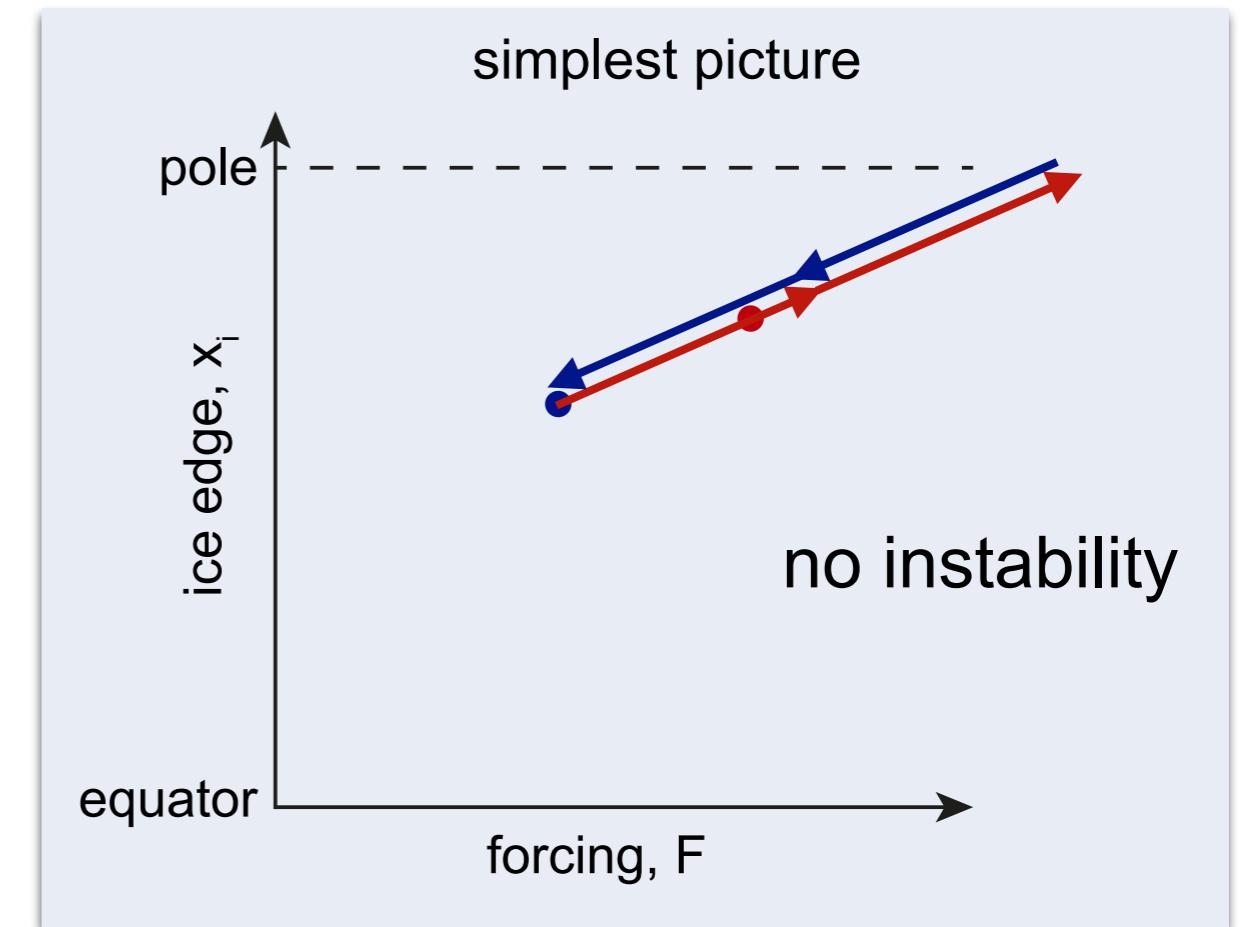
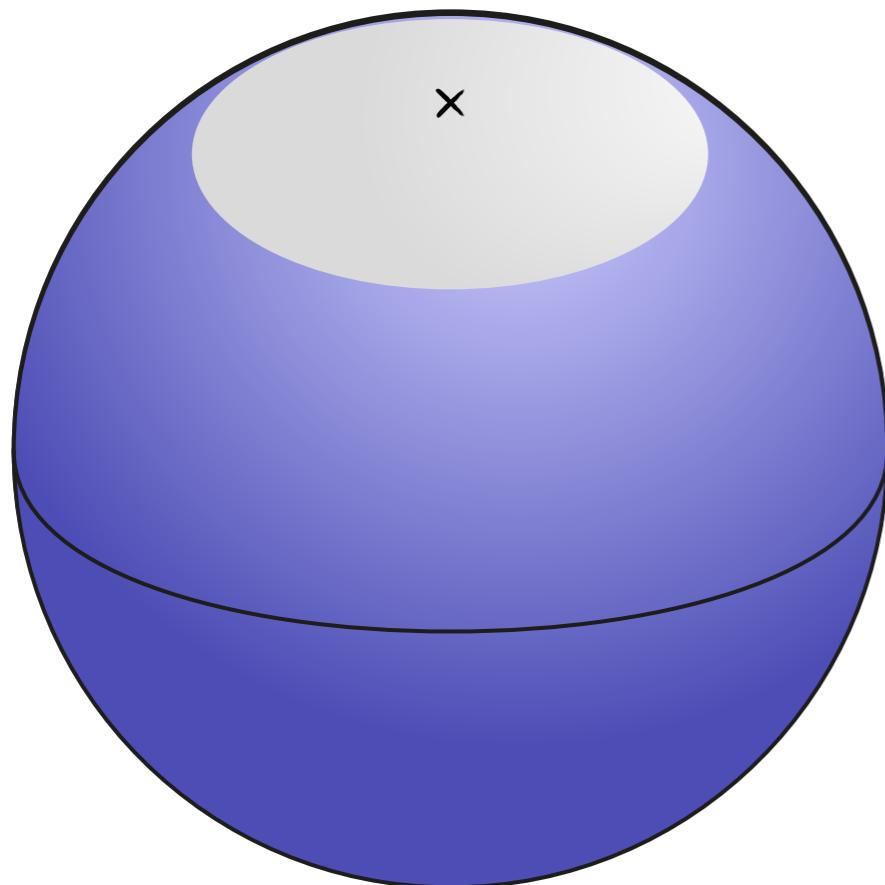
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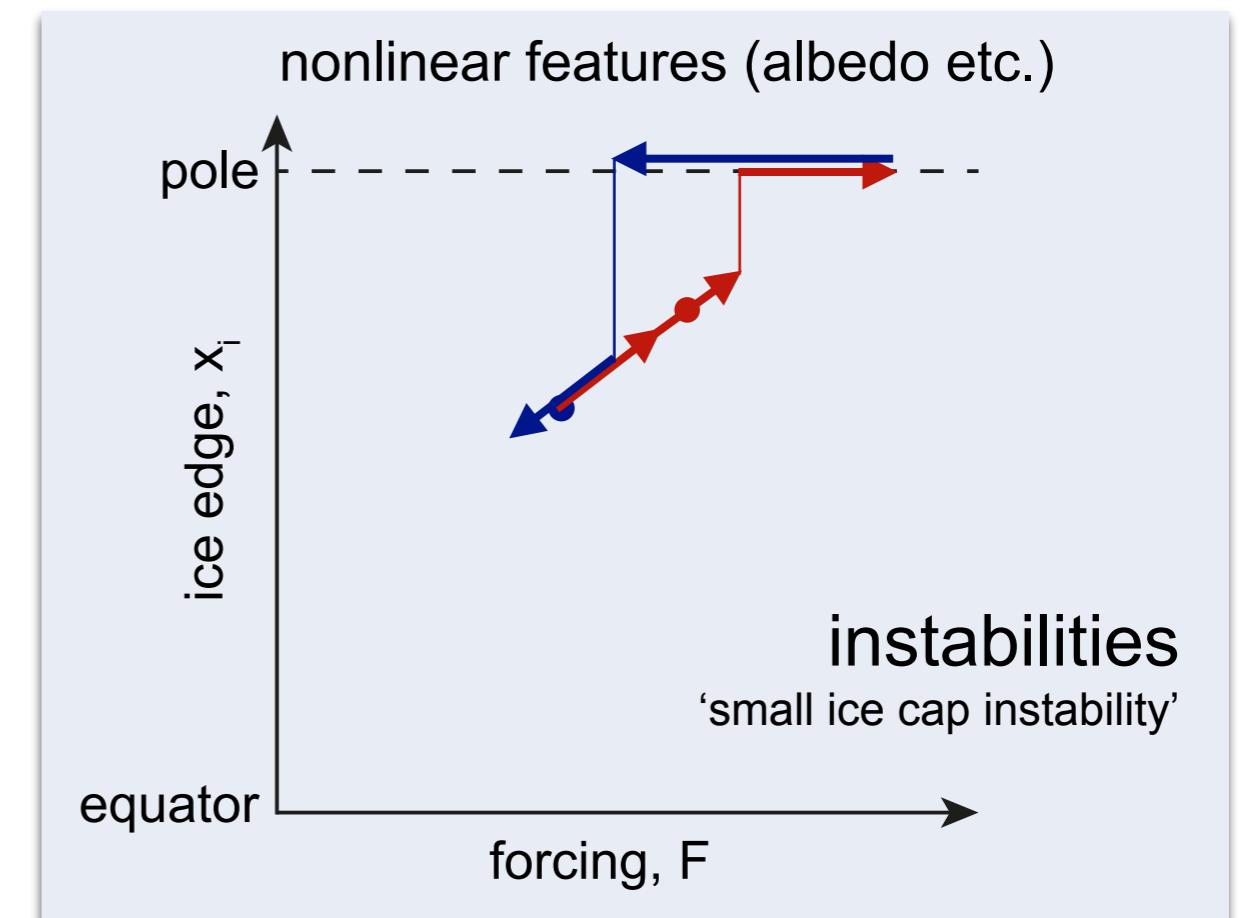
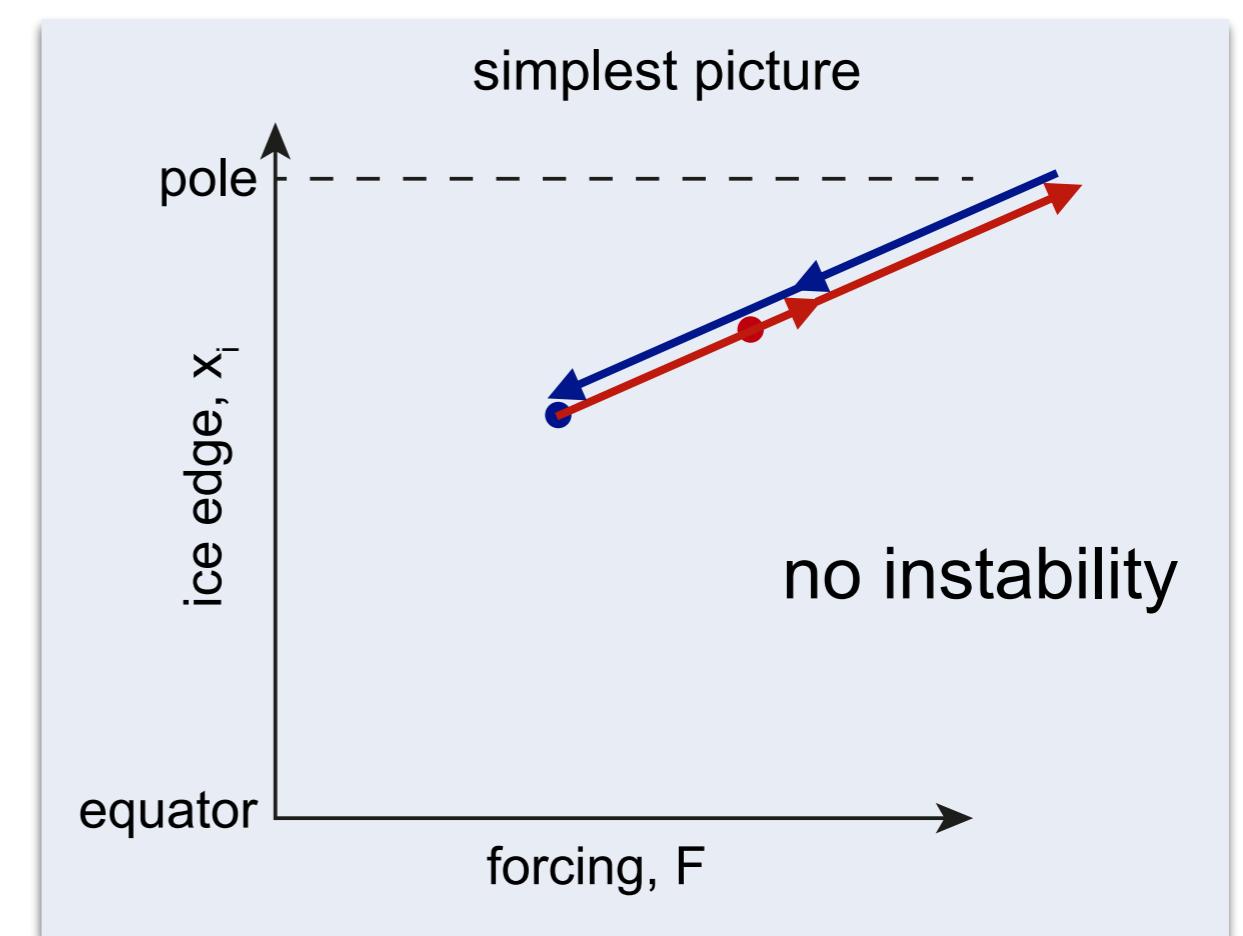




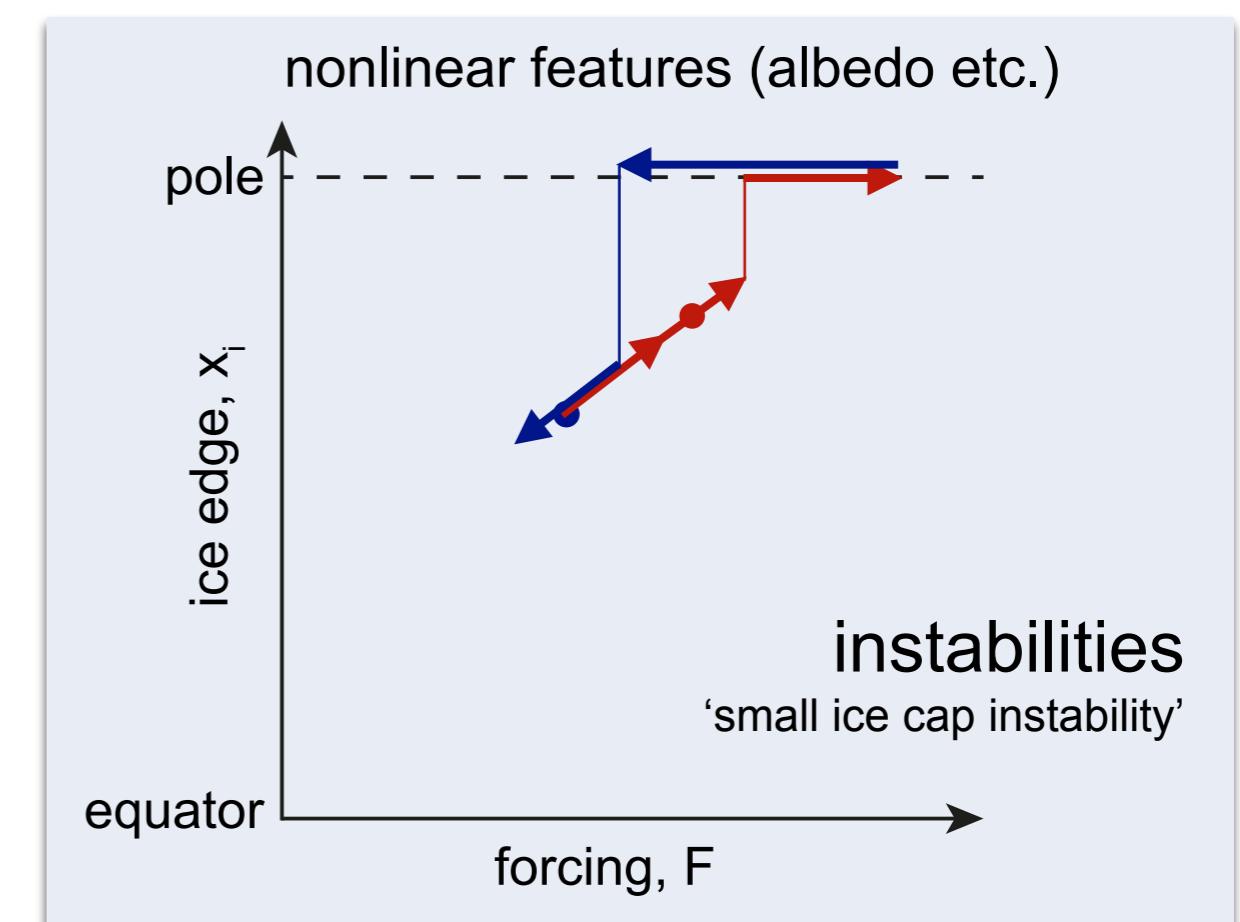
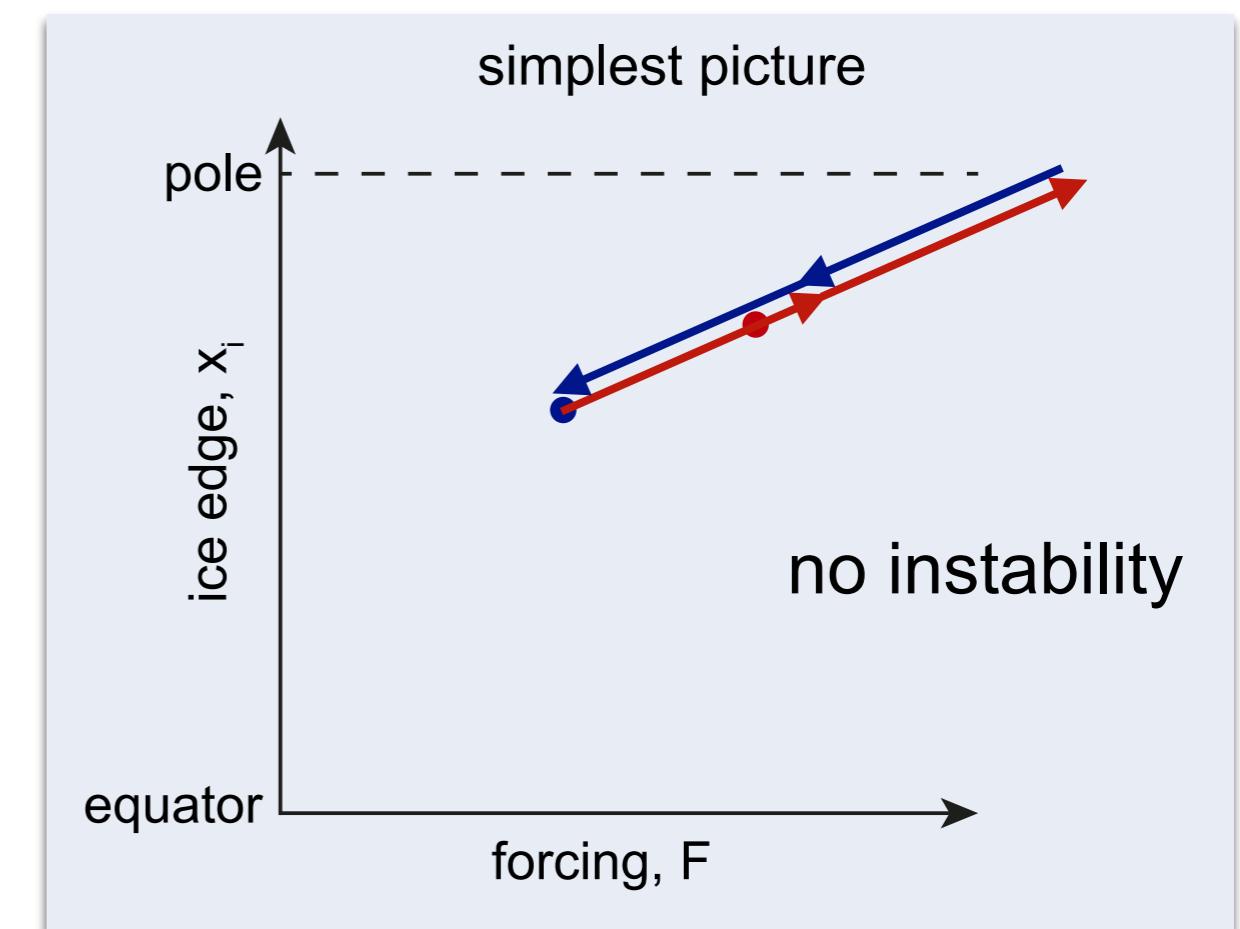
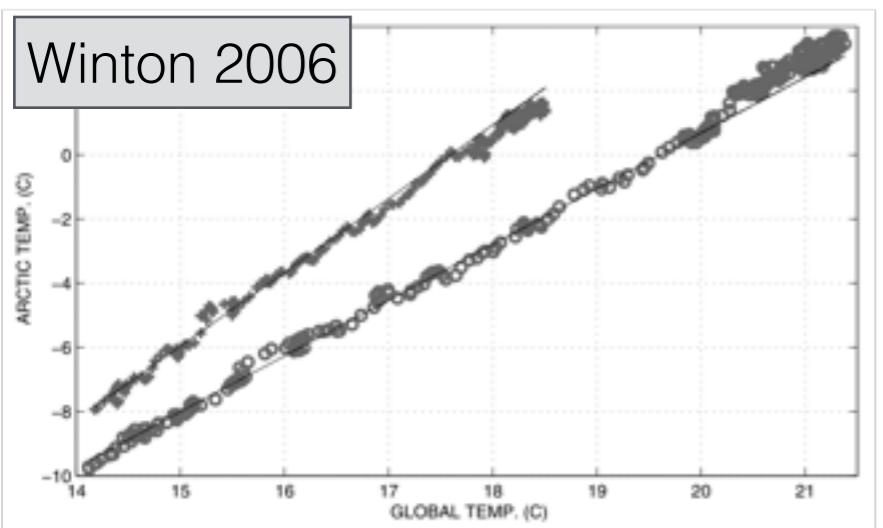




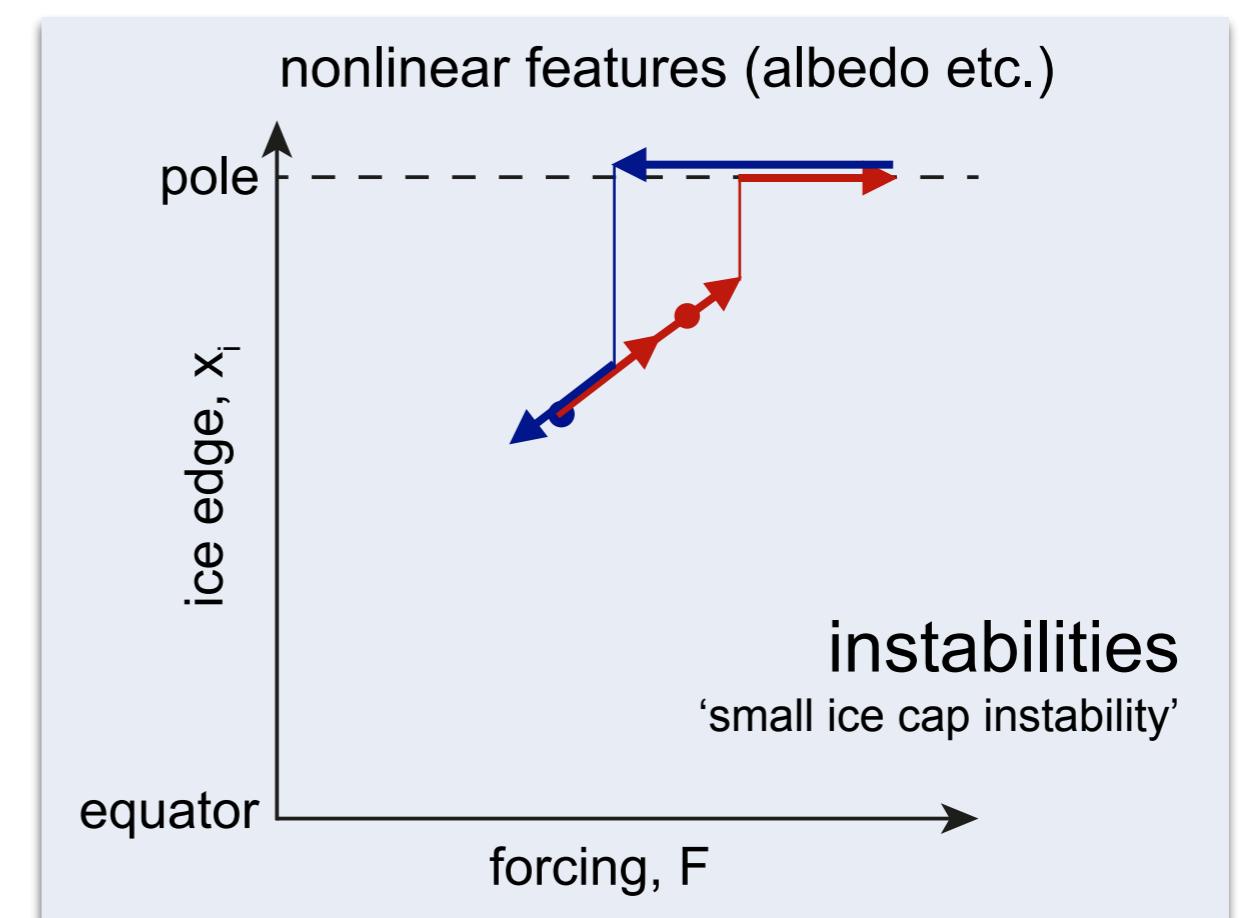
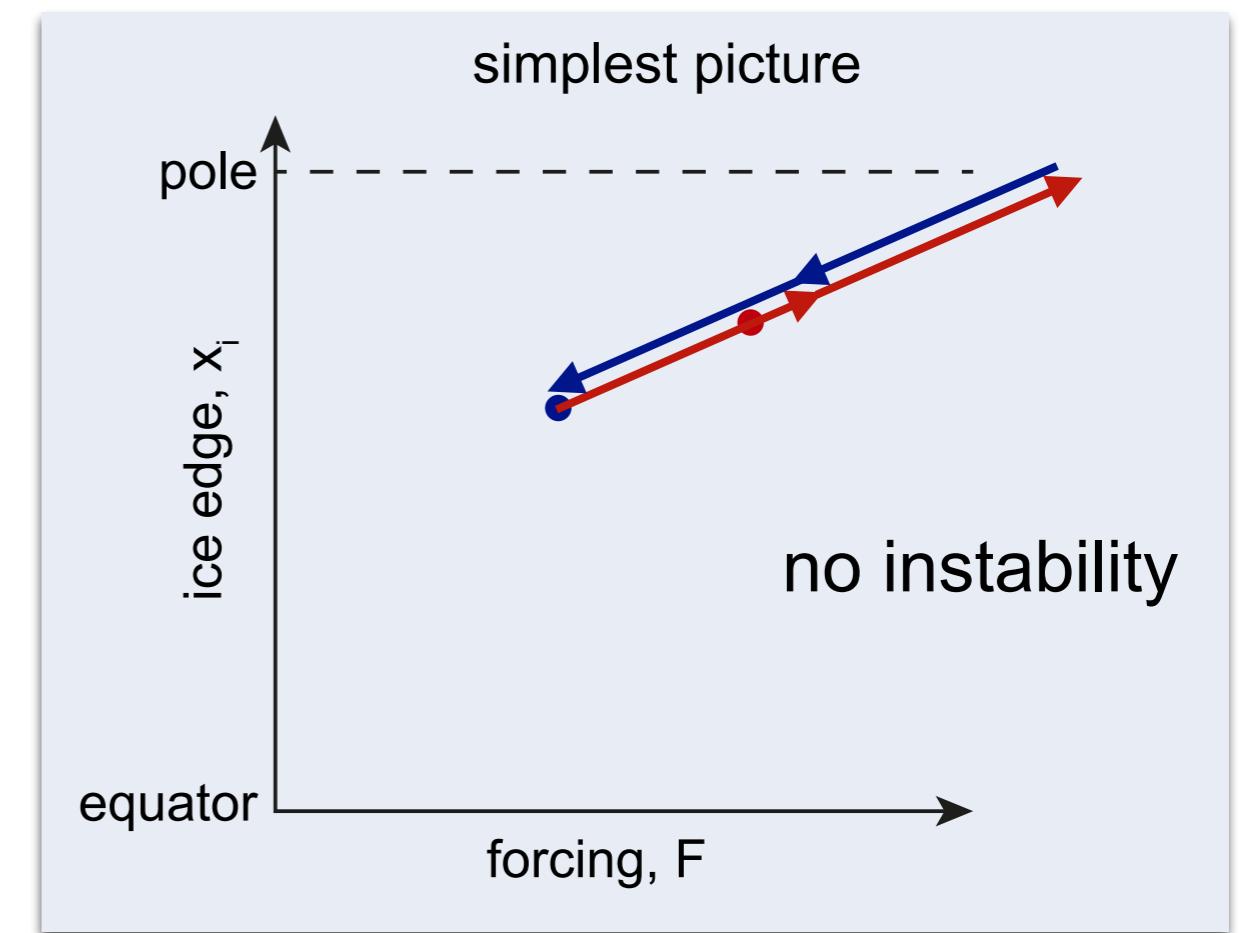
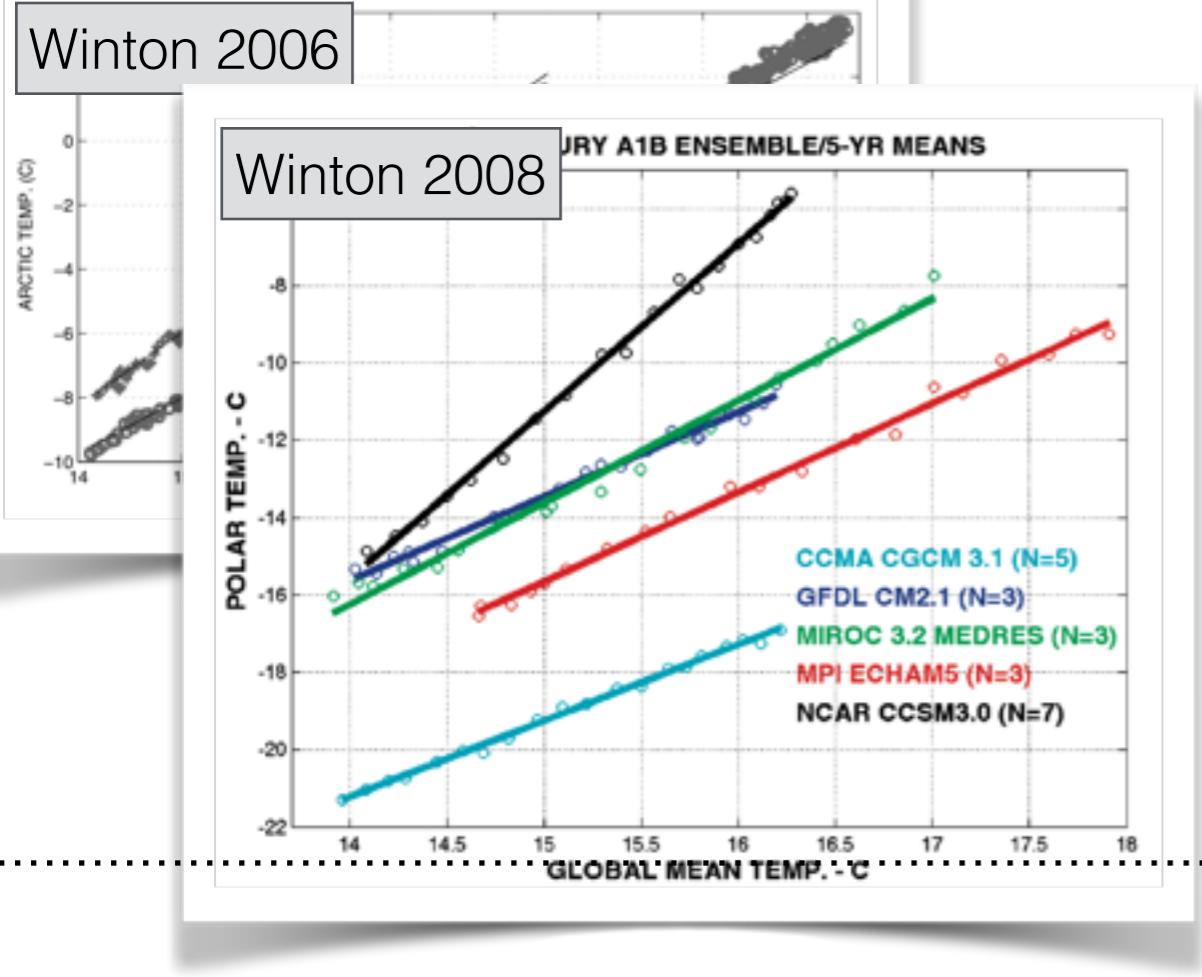
What have people found?



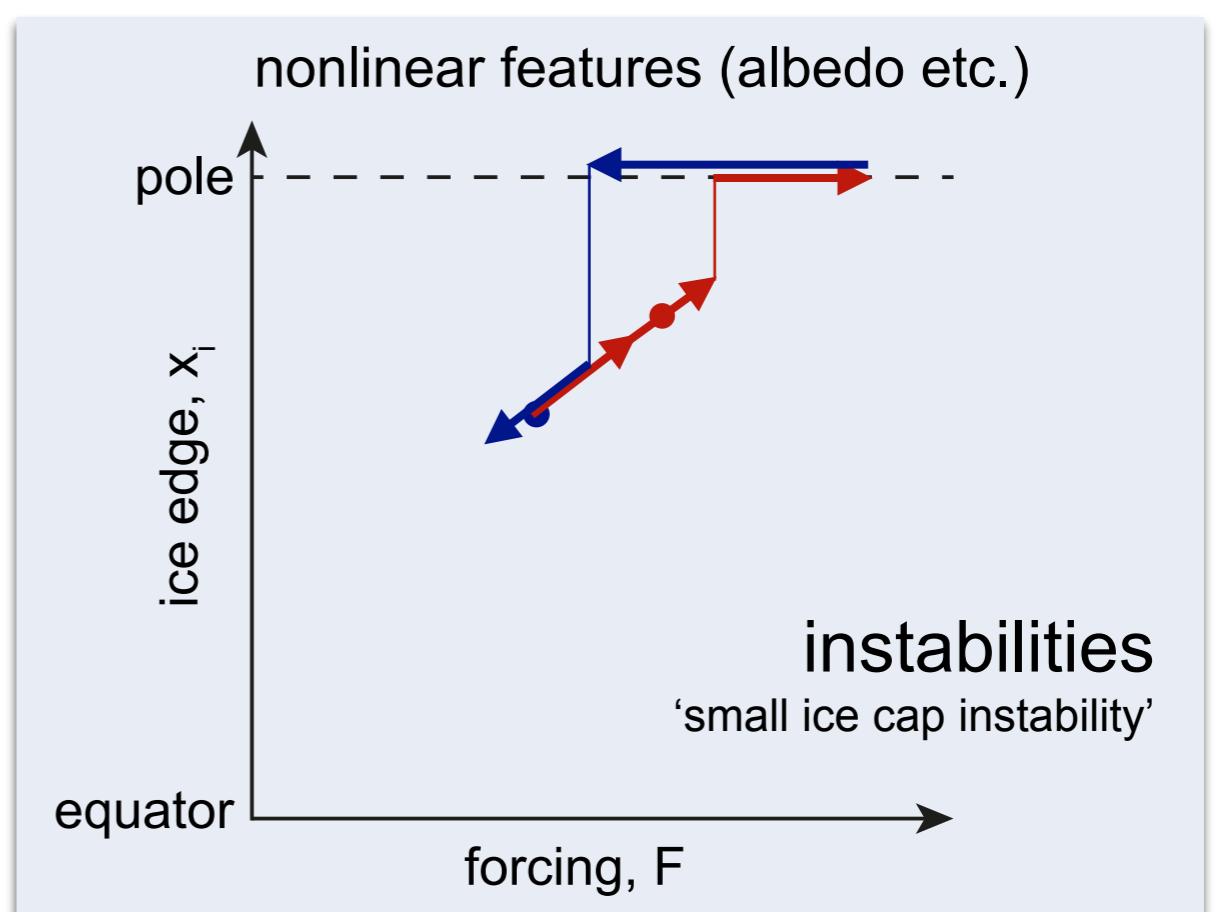
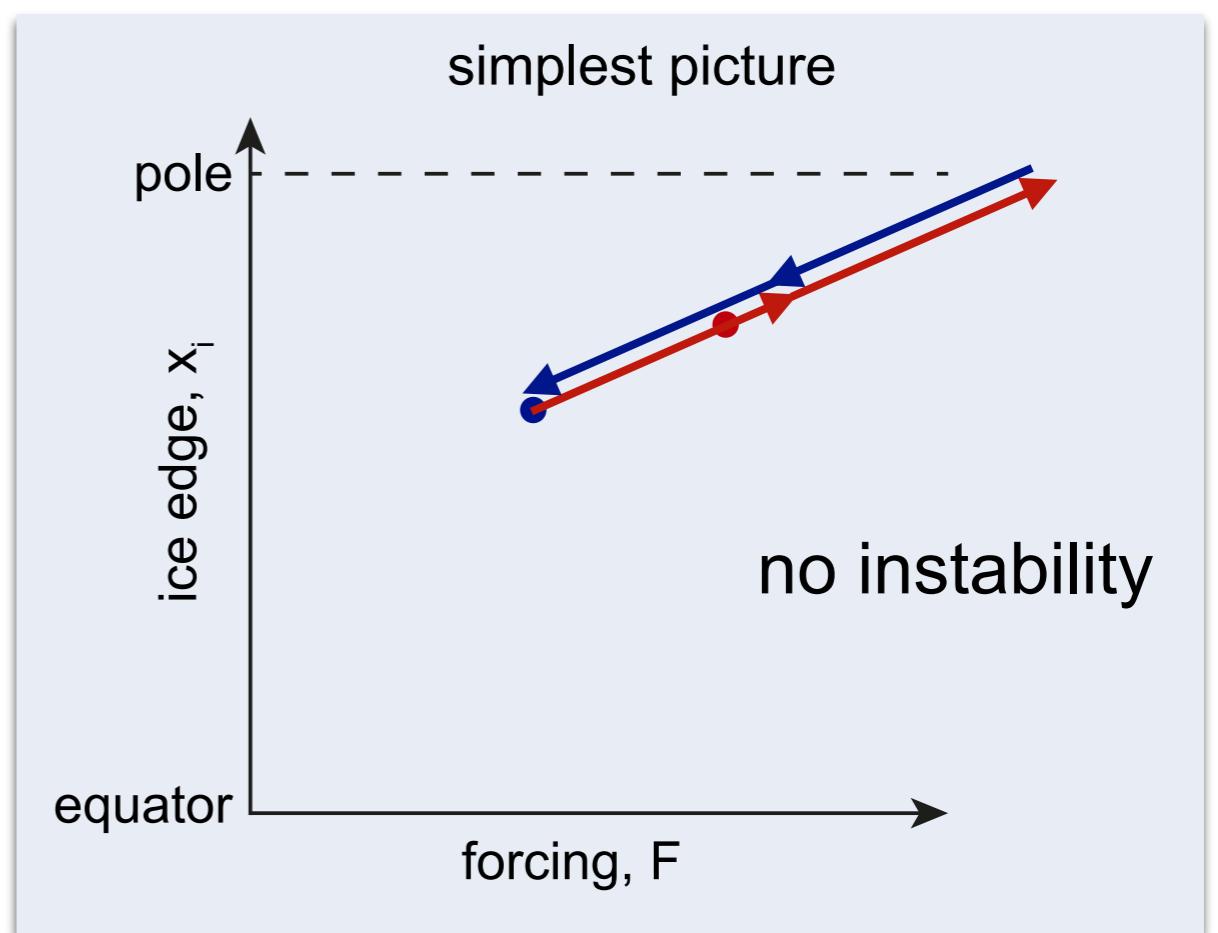
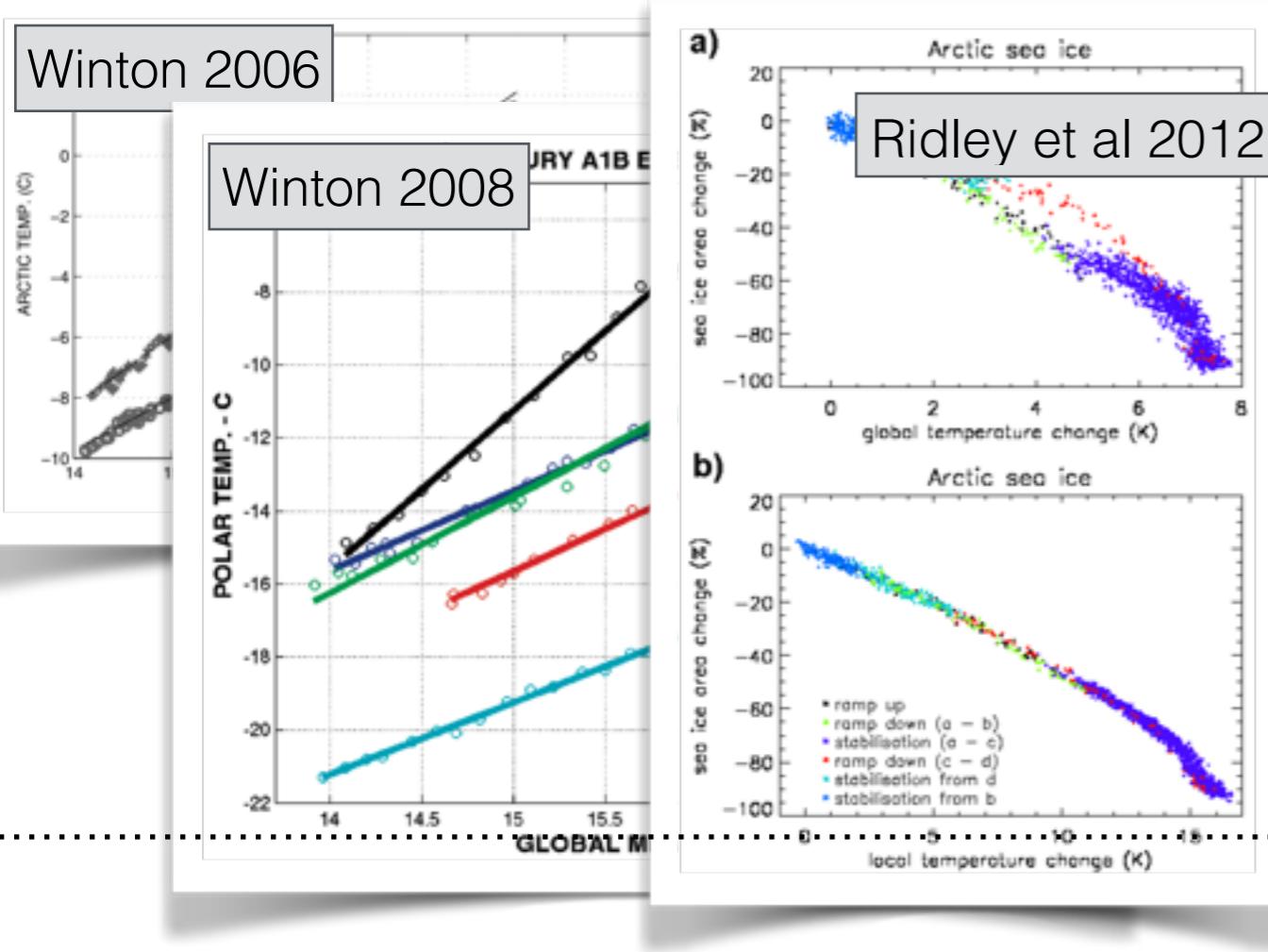
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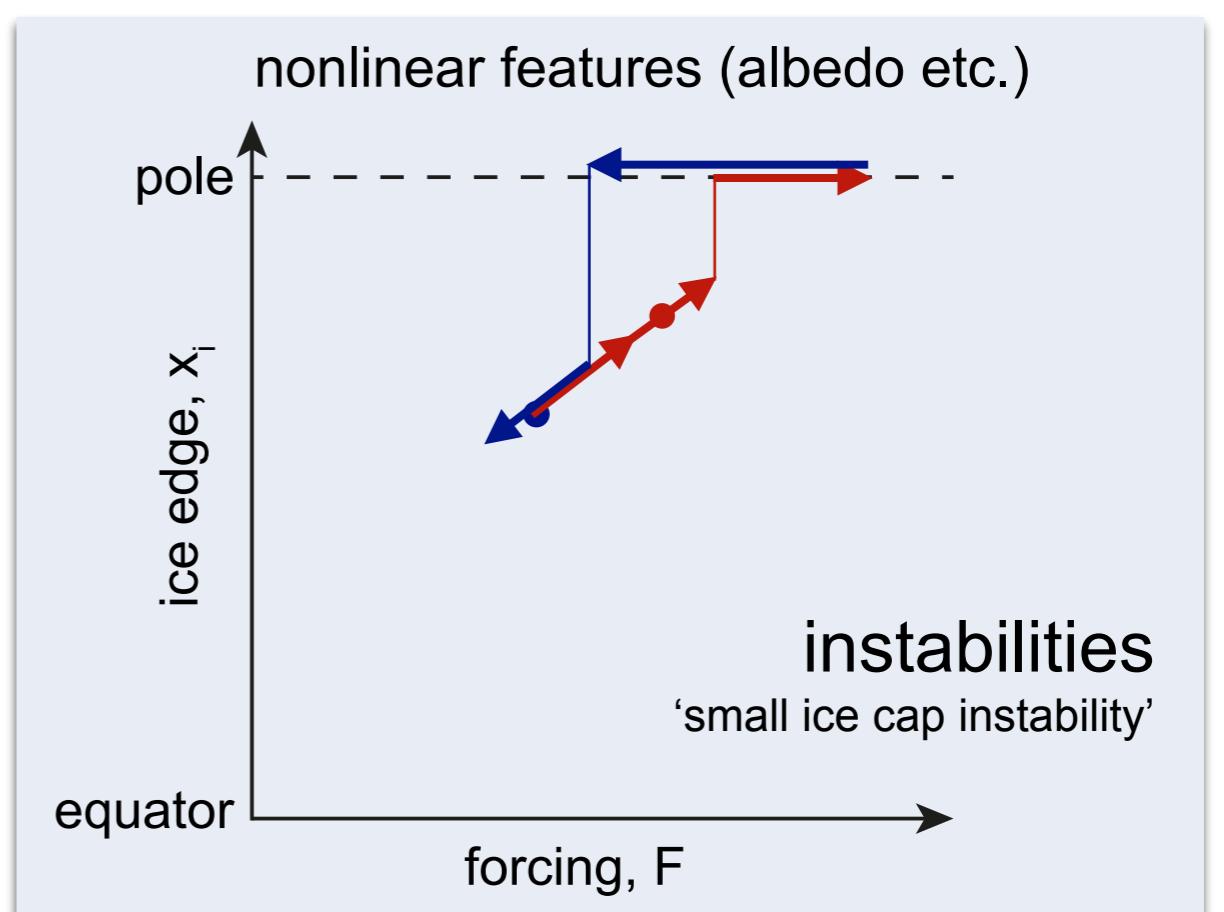
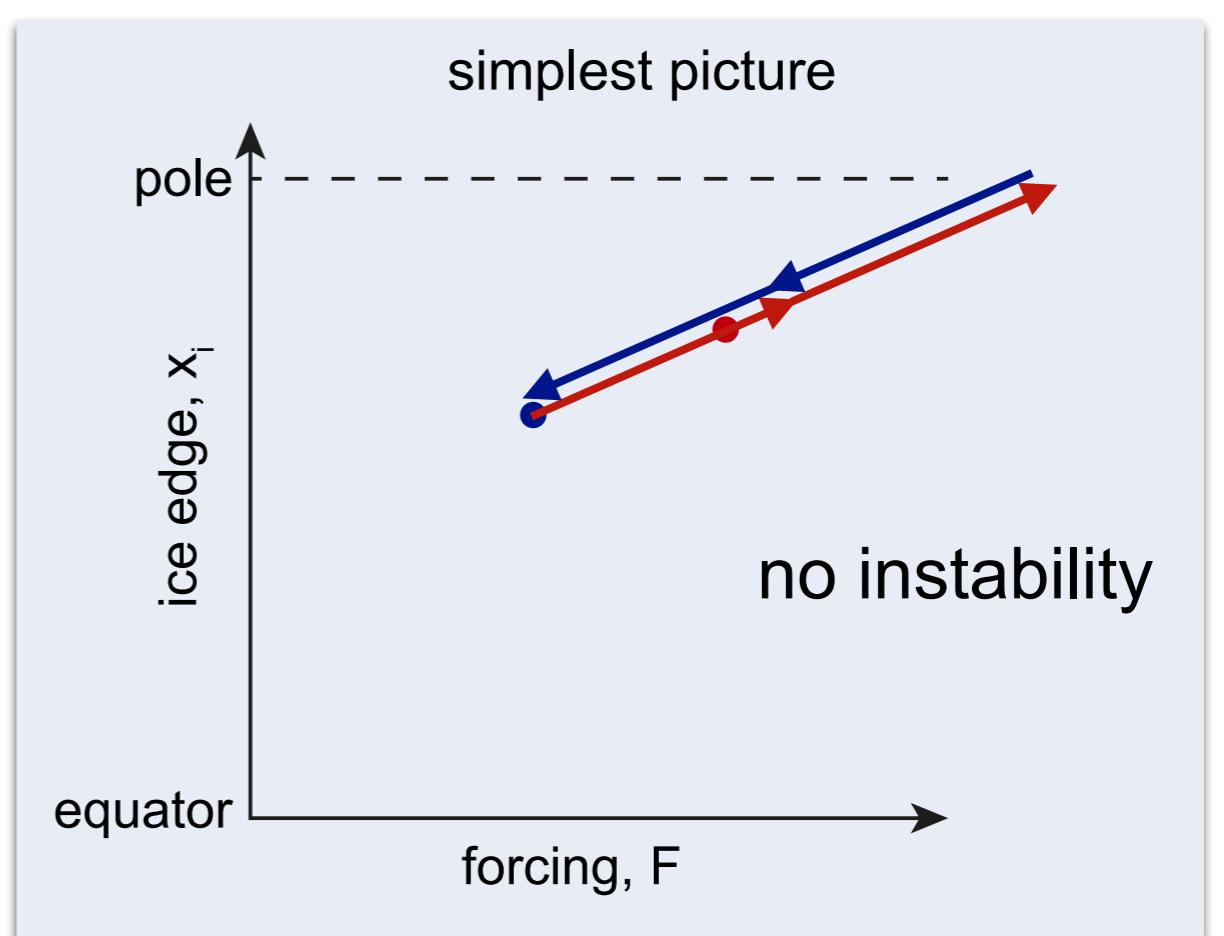
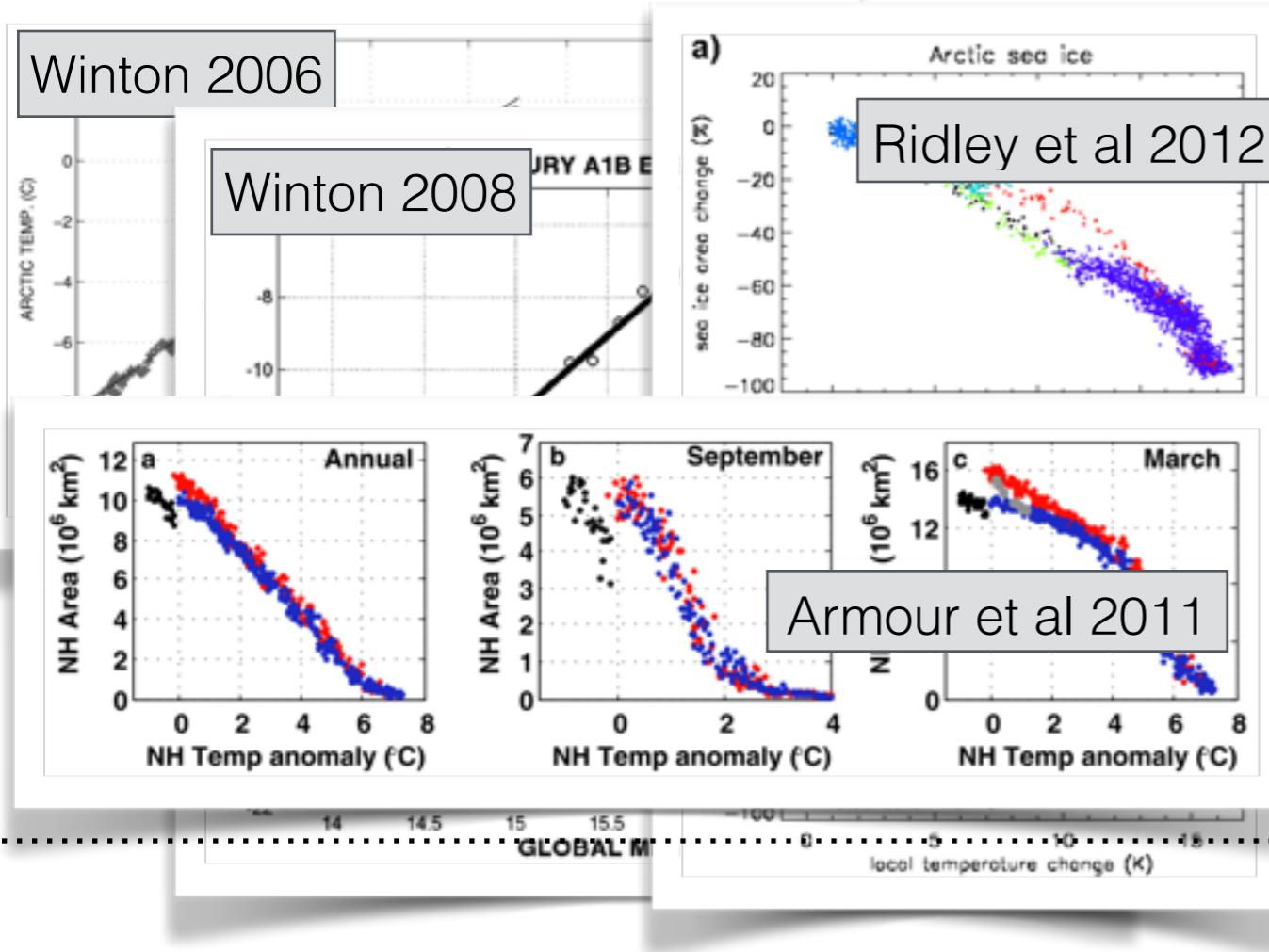
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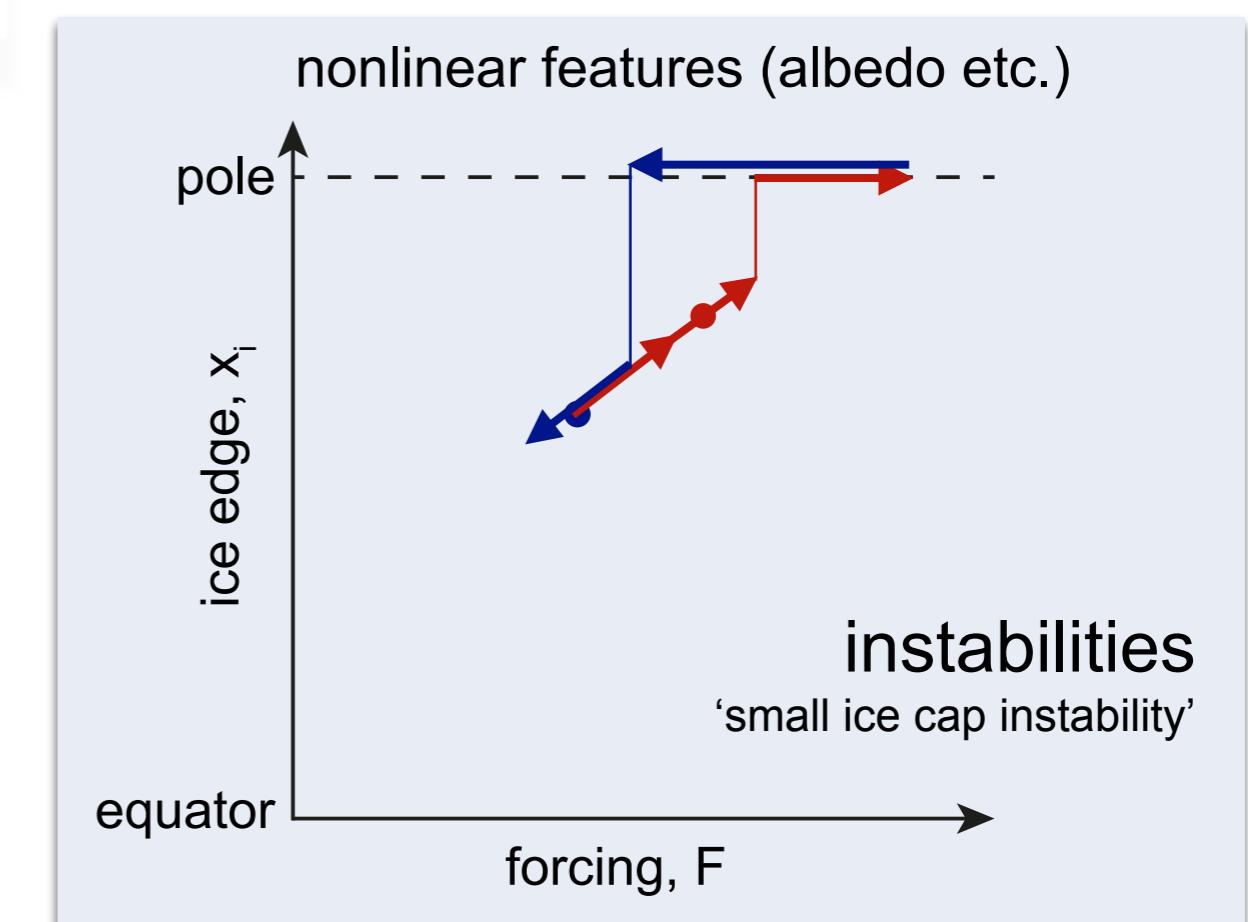
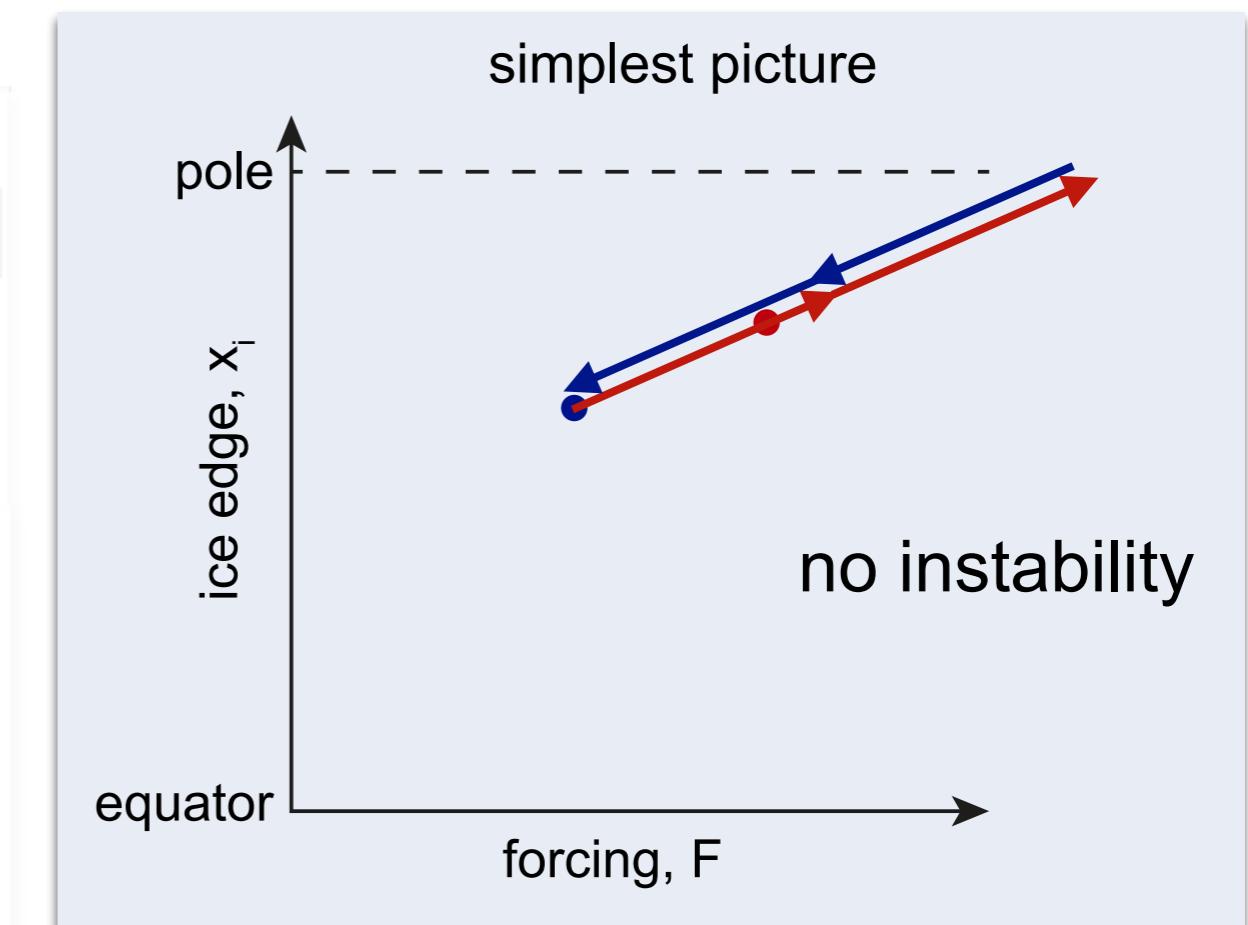
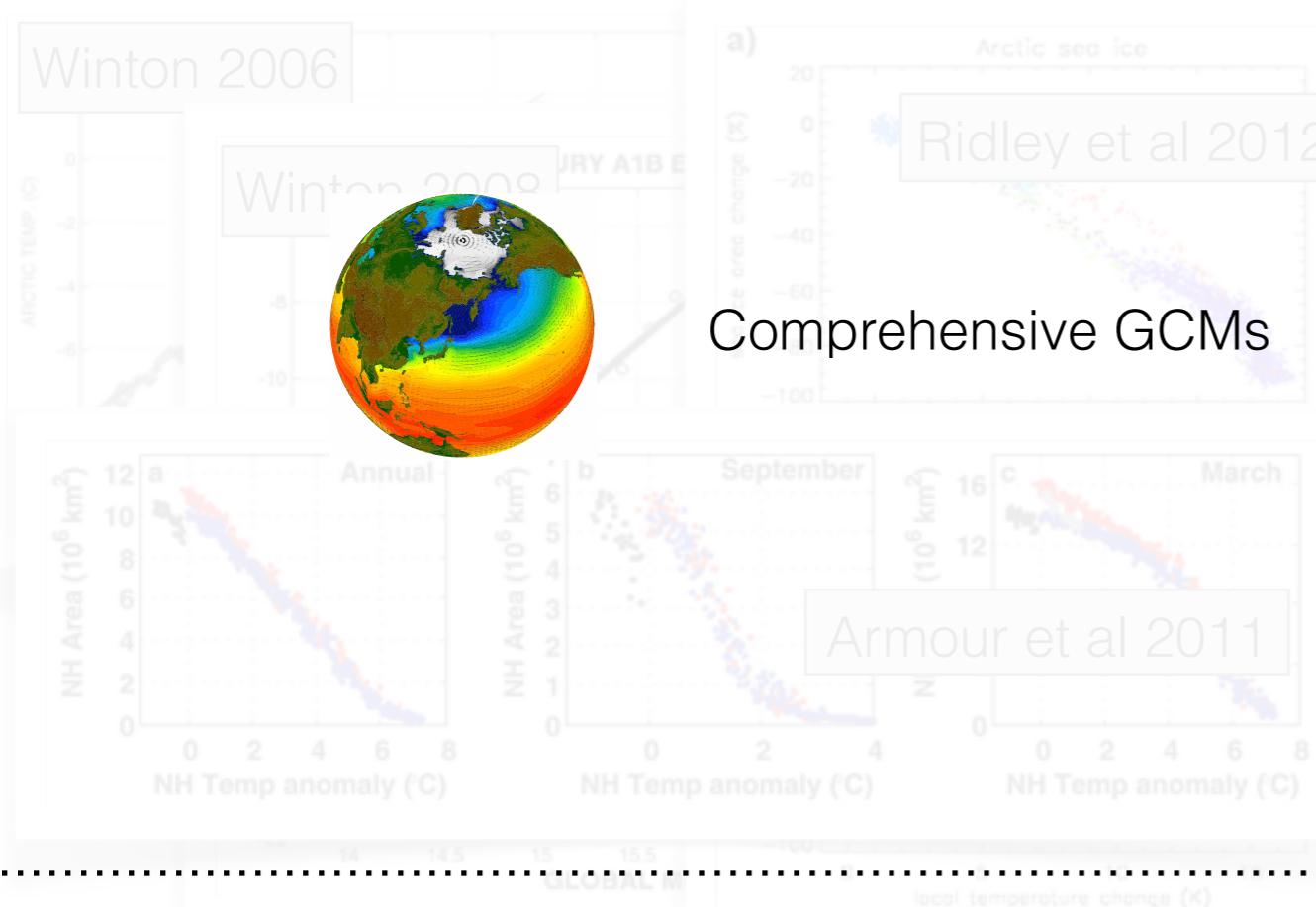
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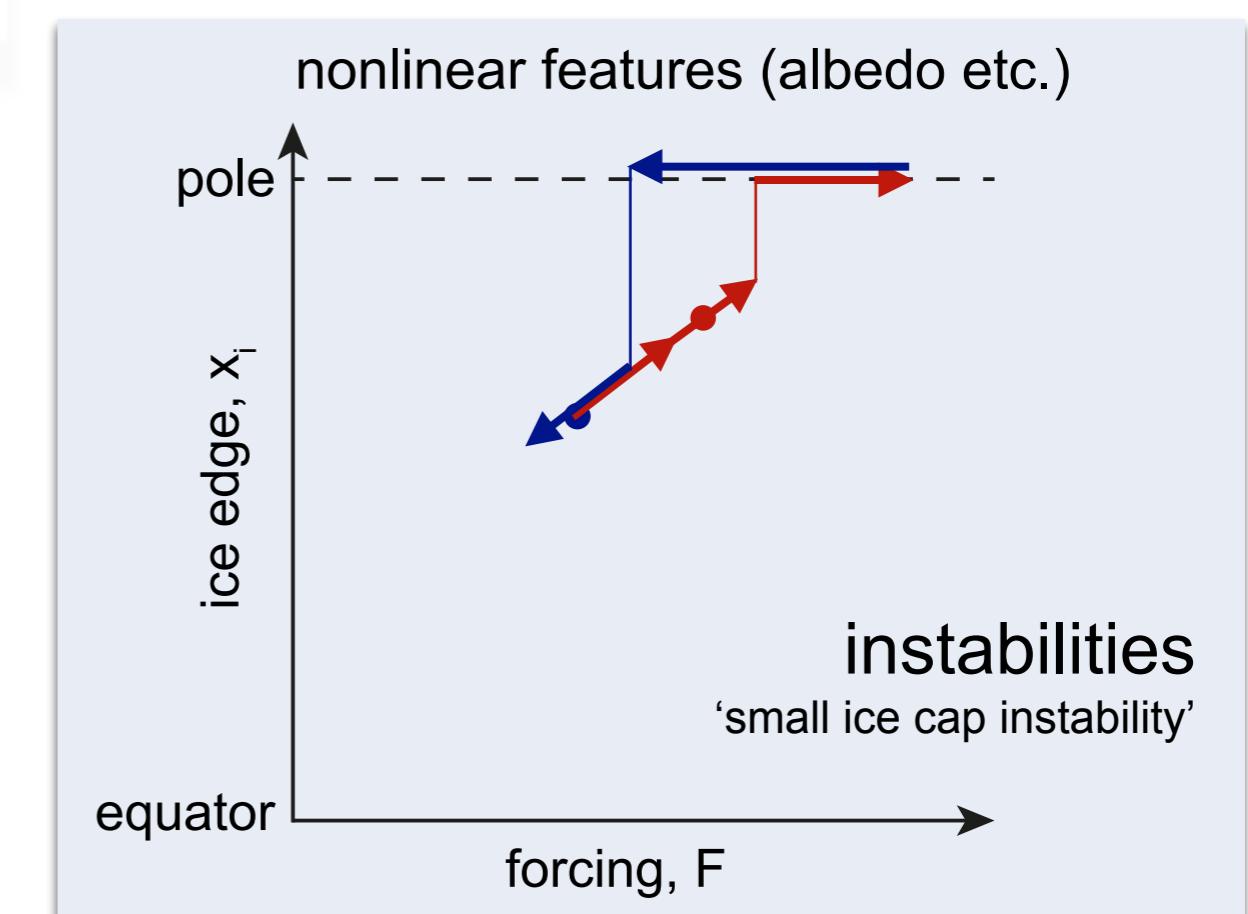
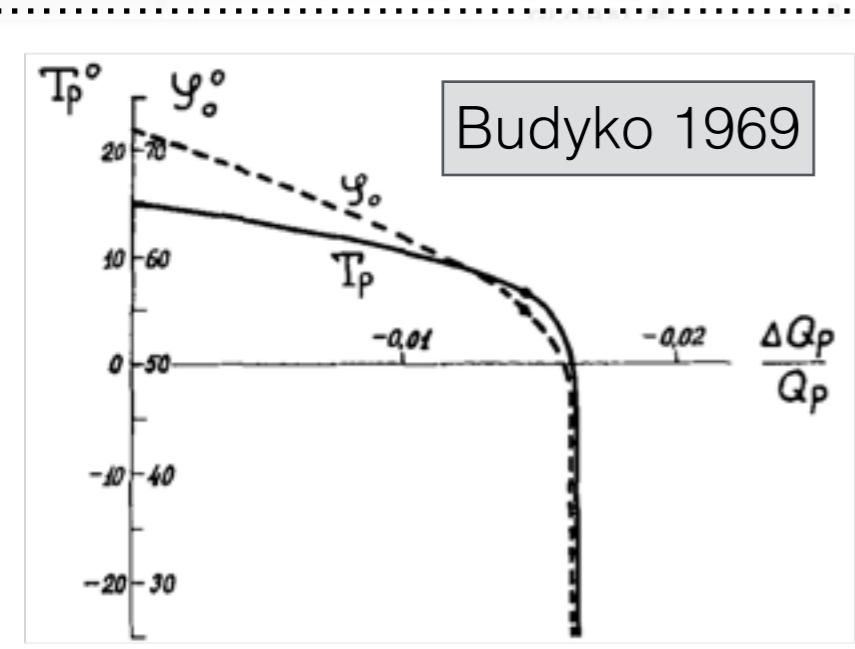
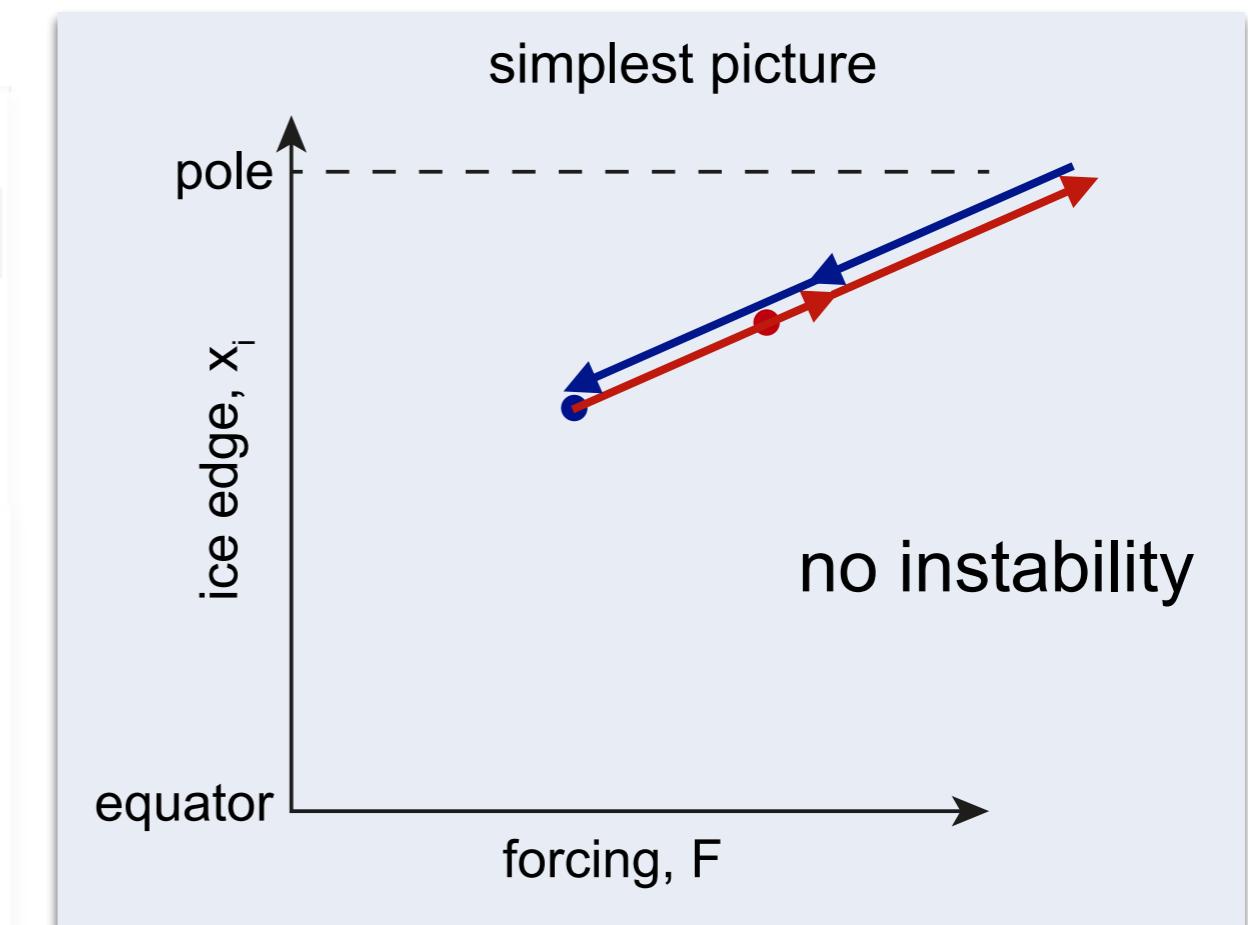
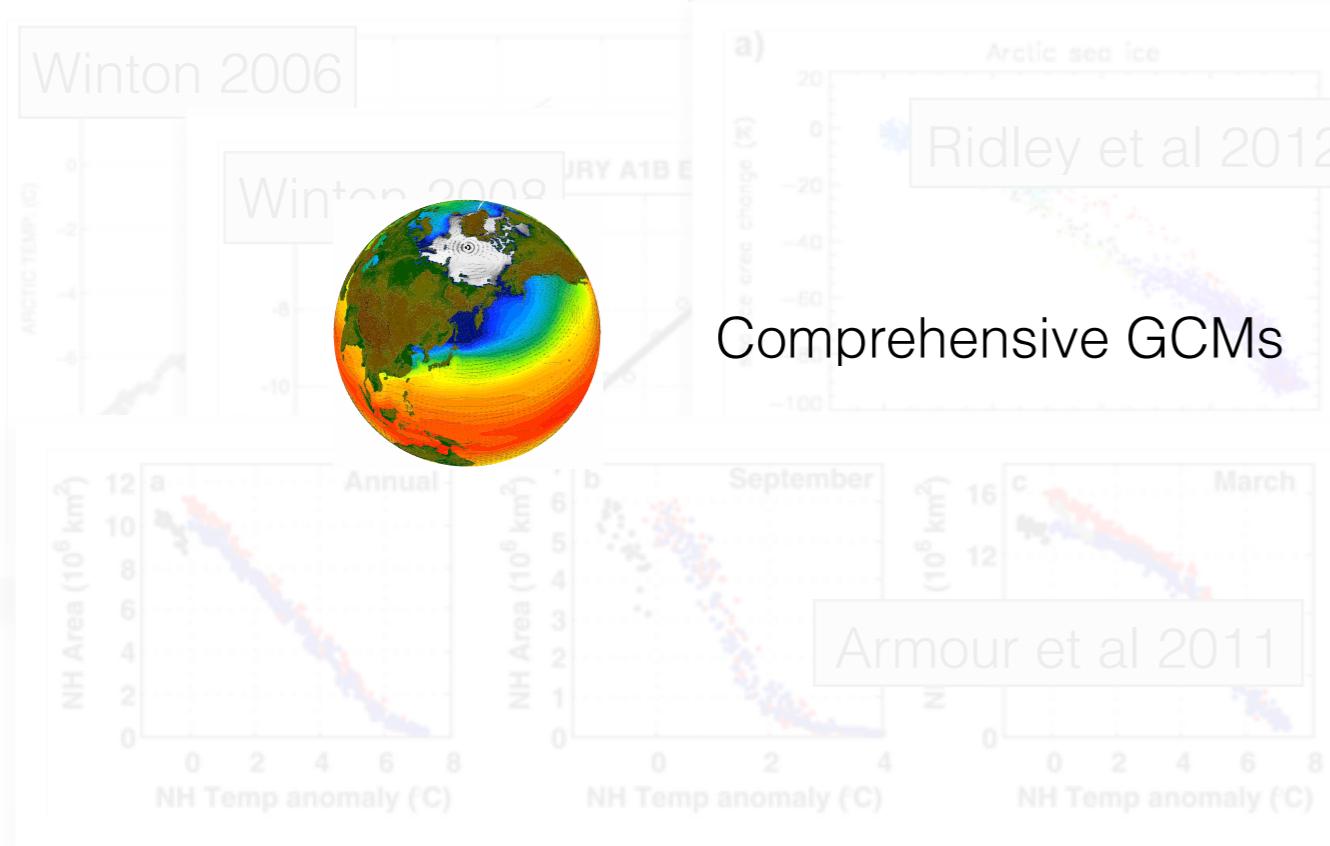
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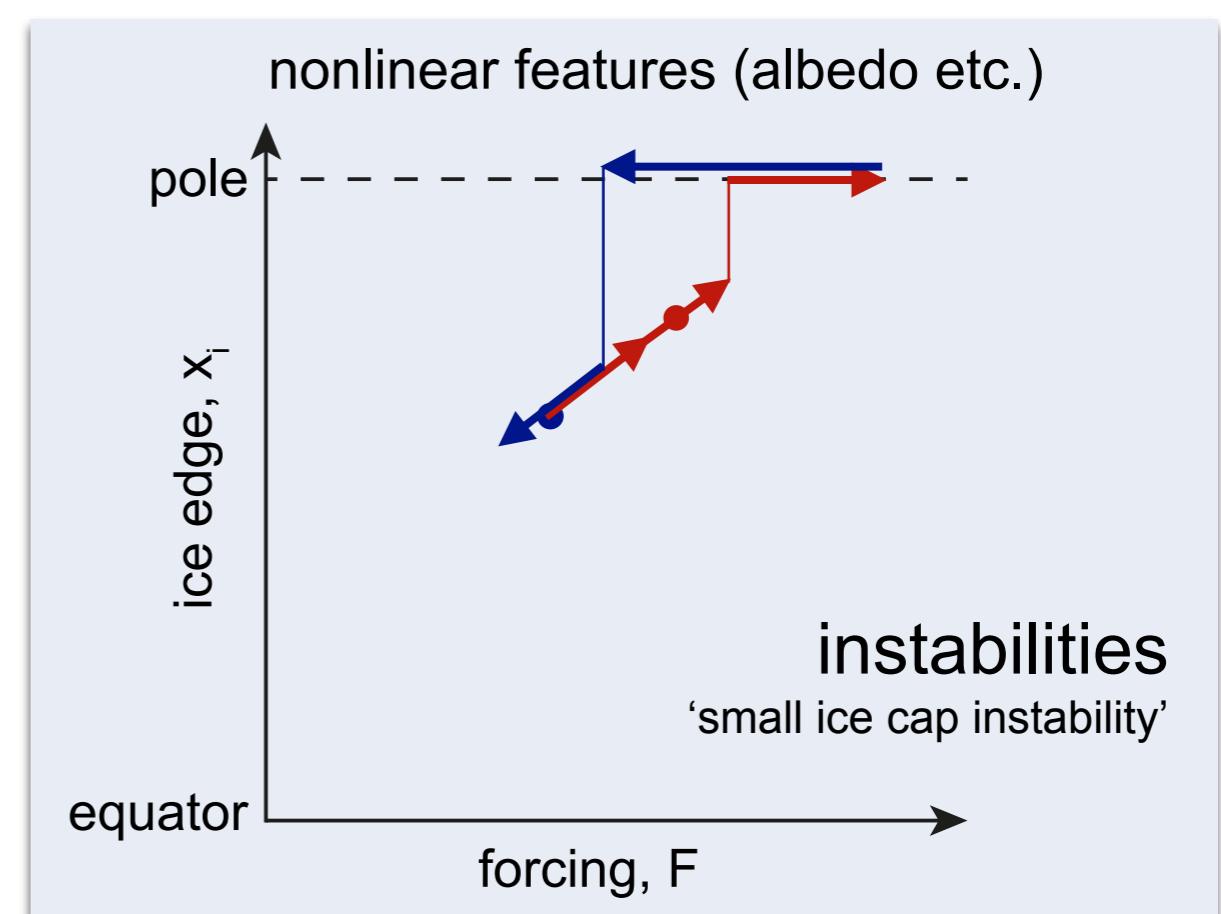
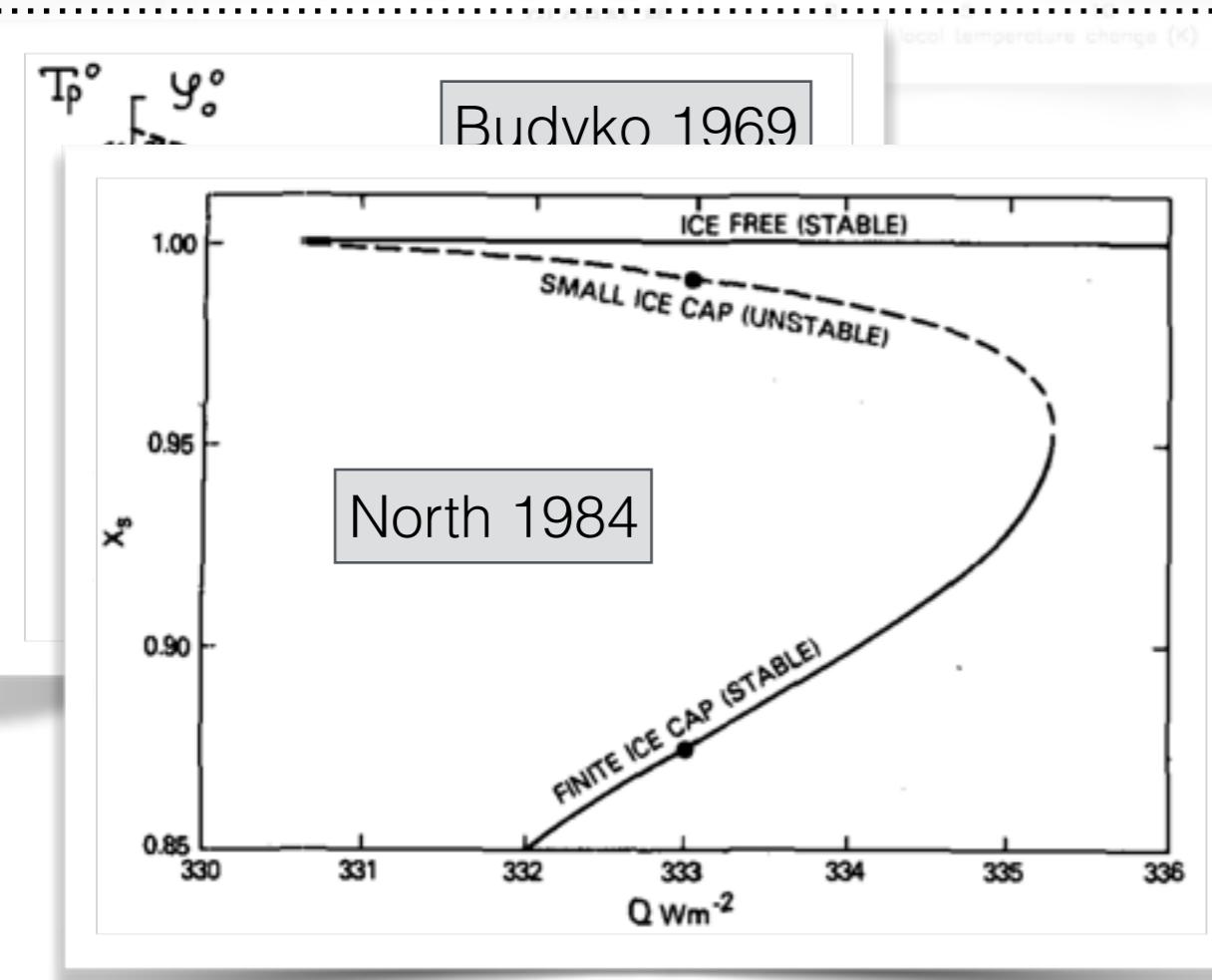
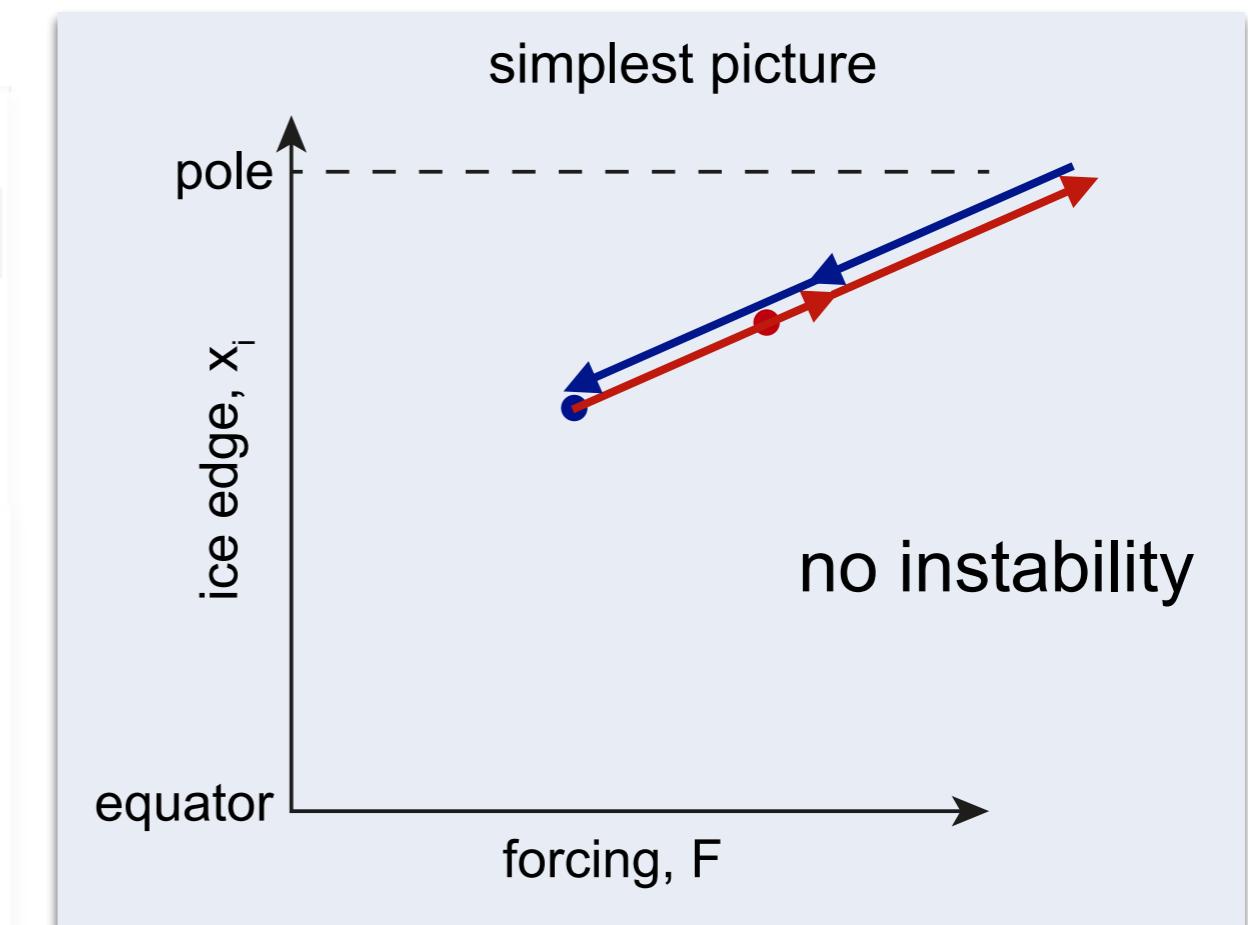
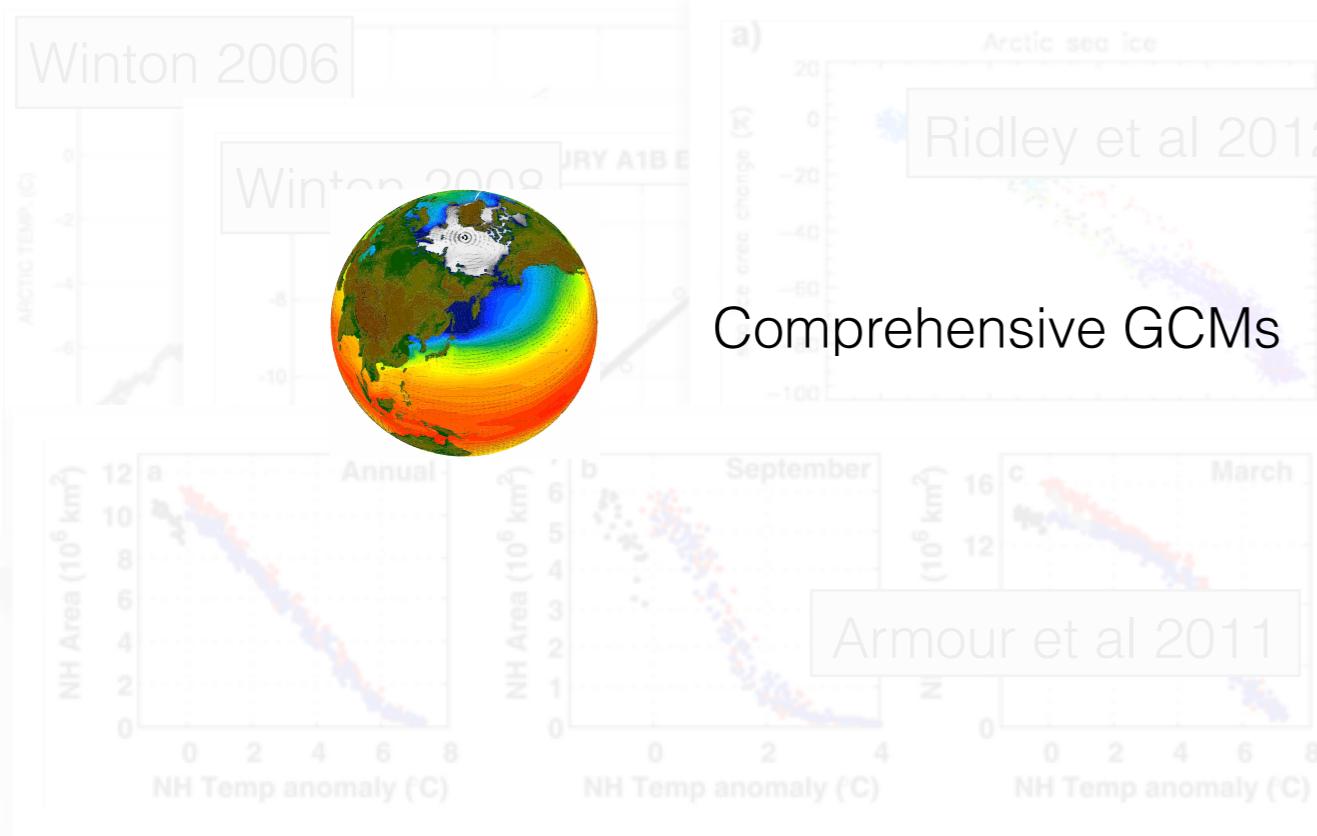
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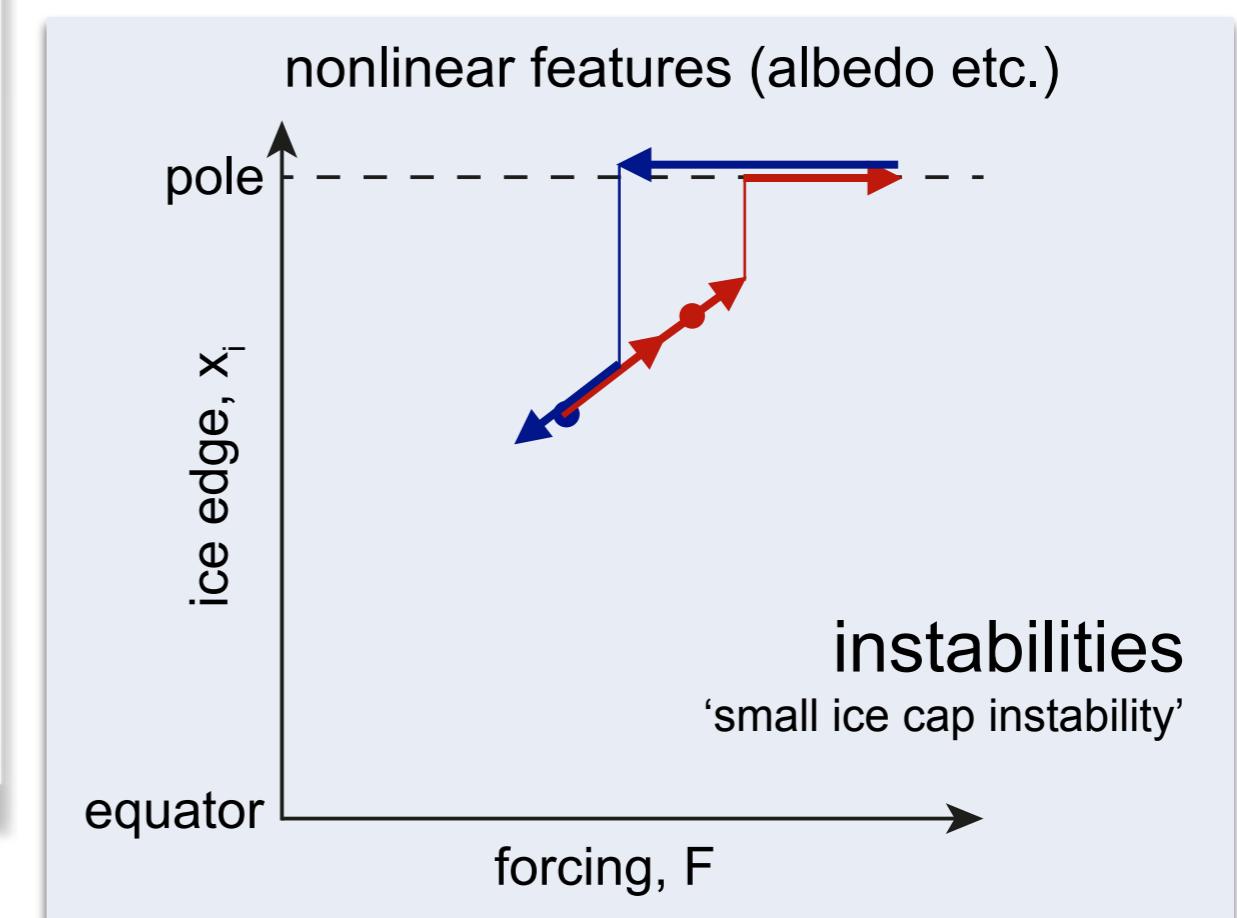
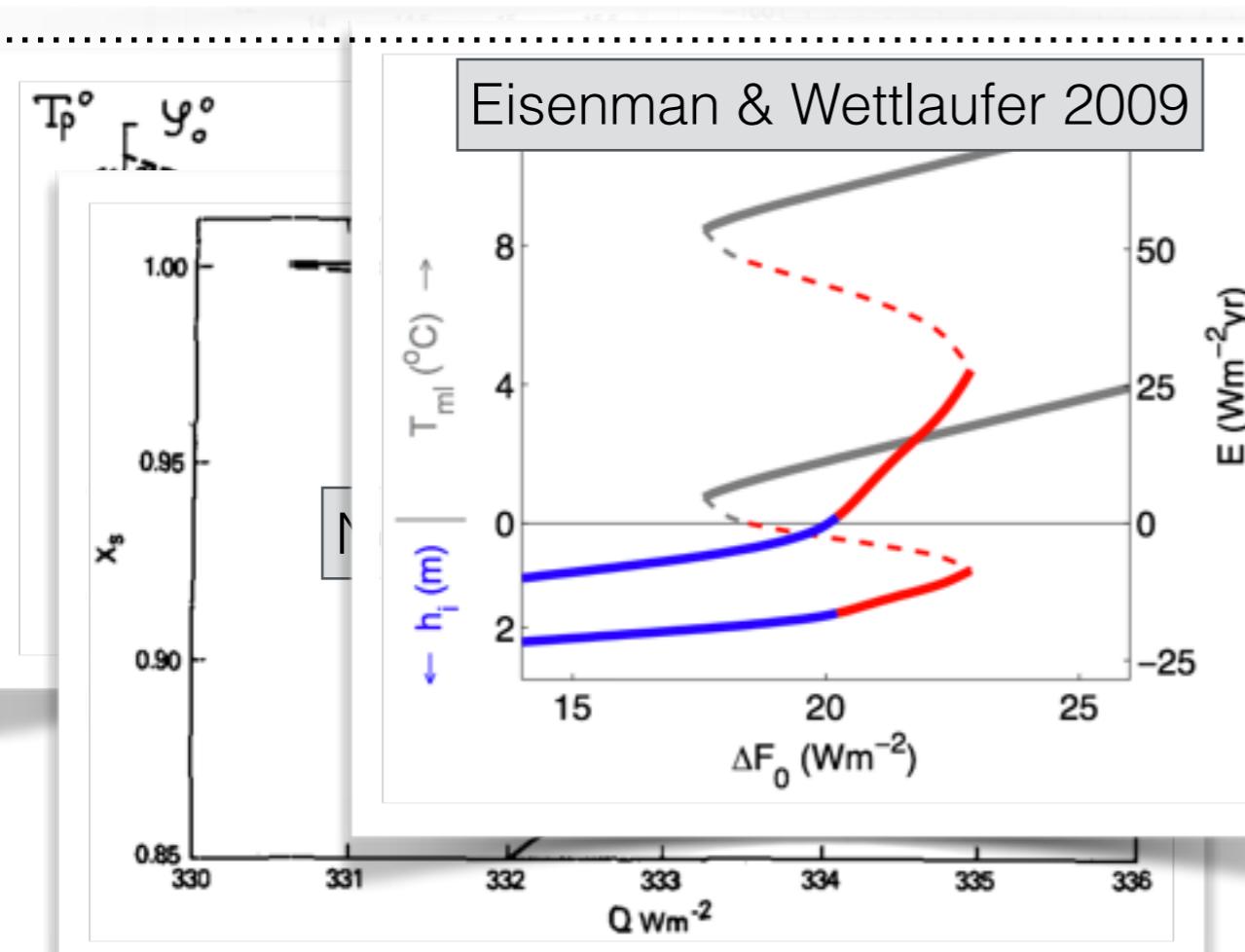
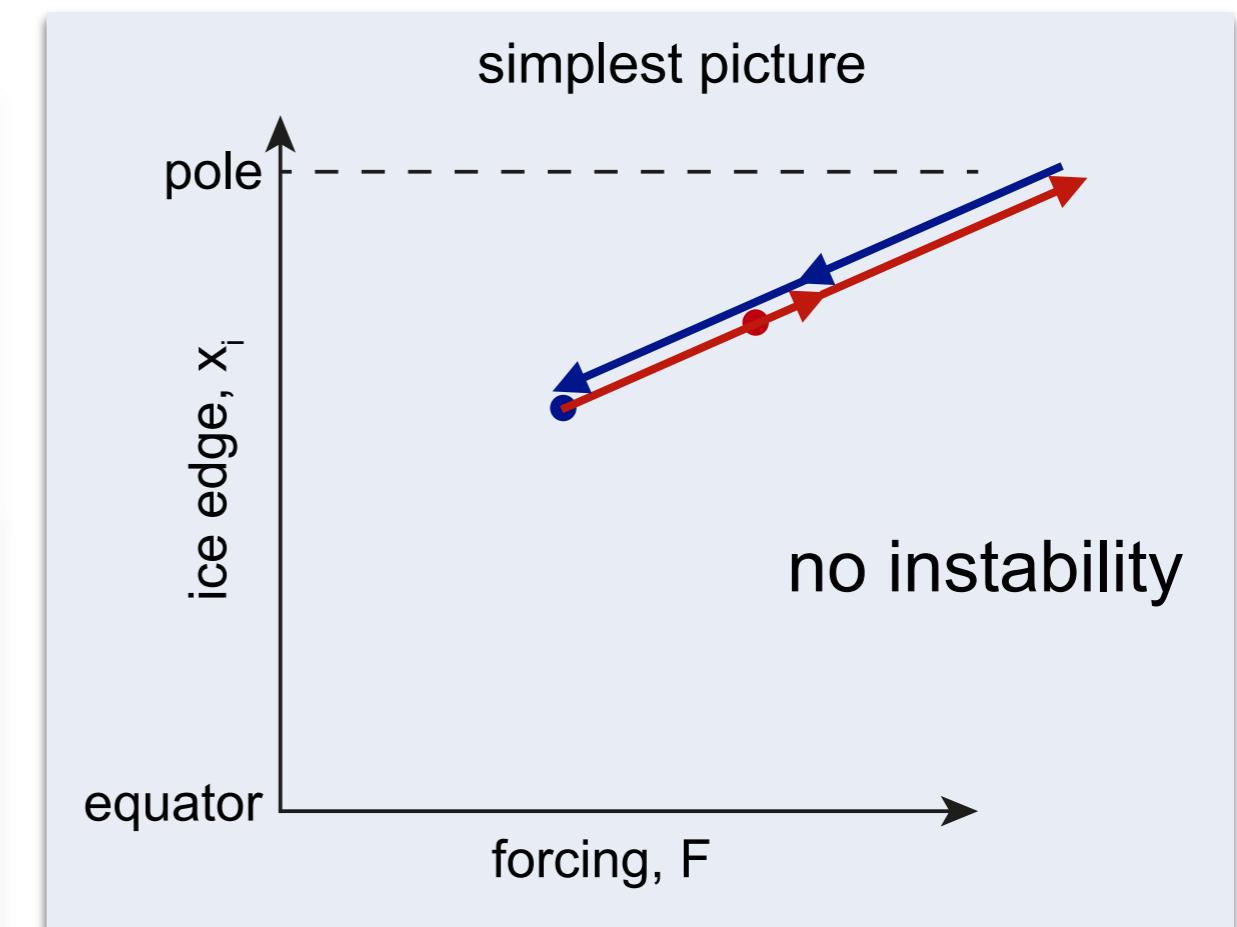
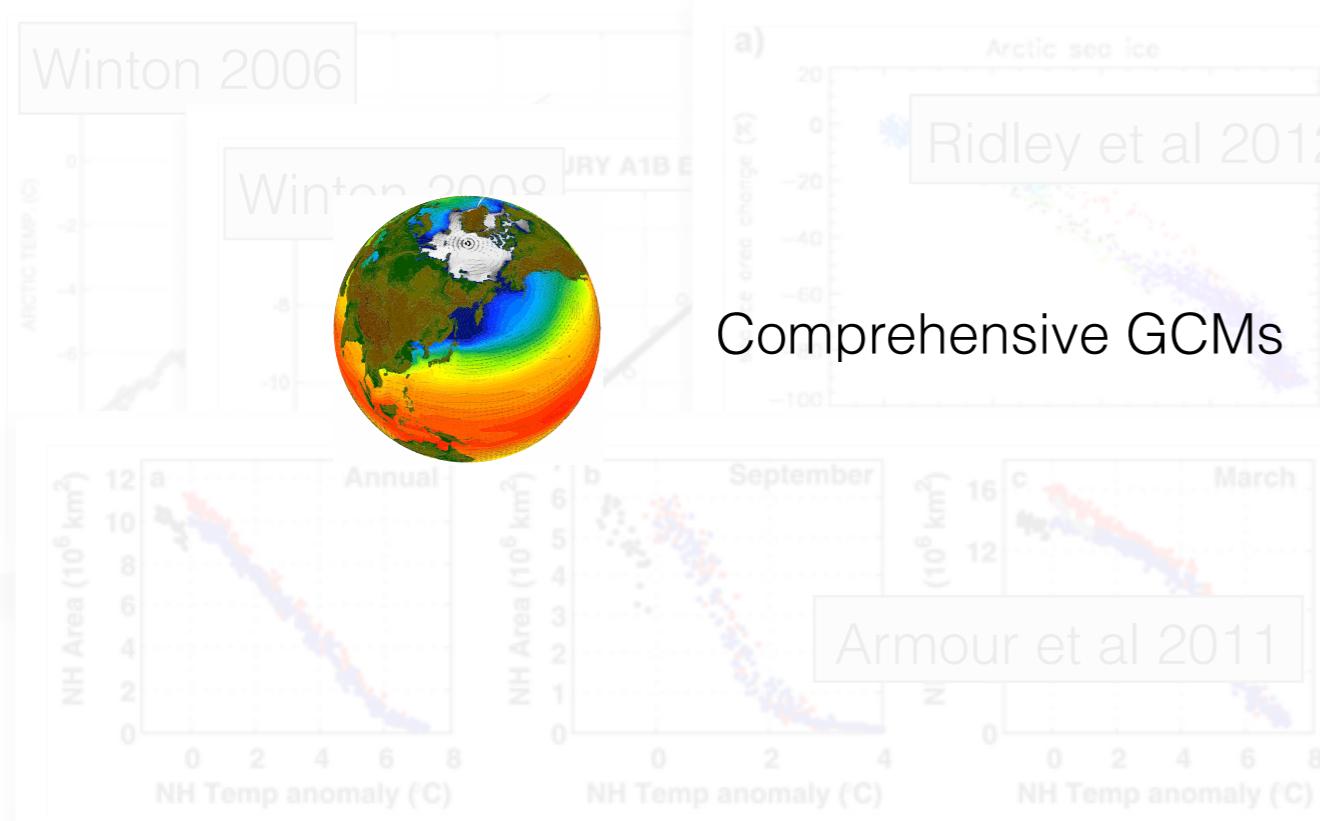
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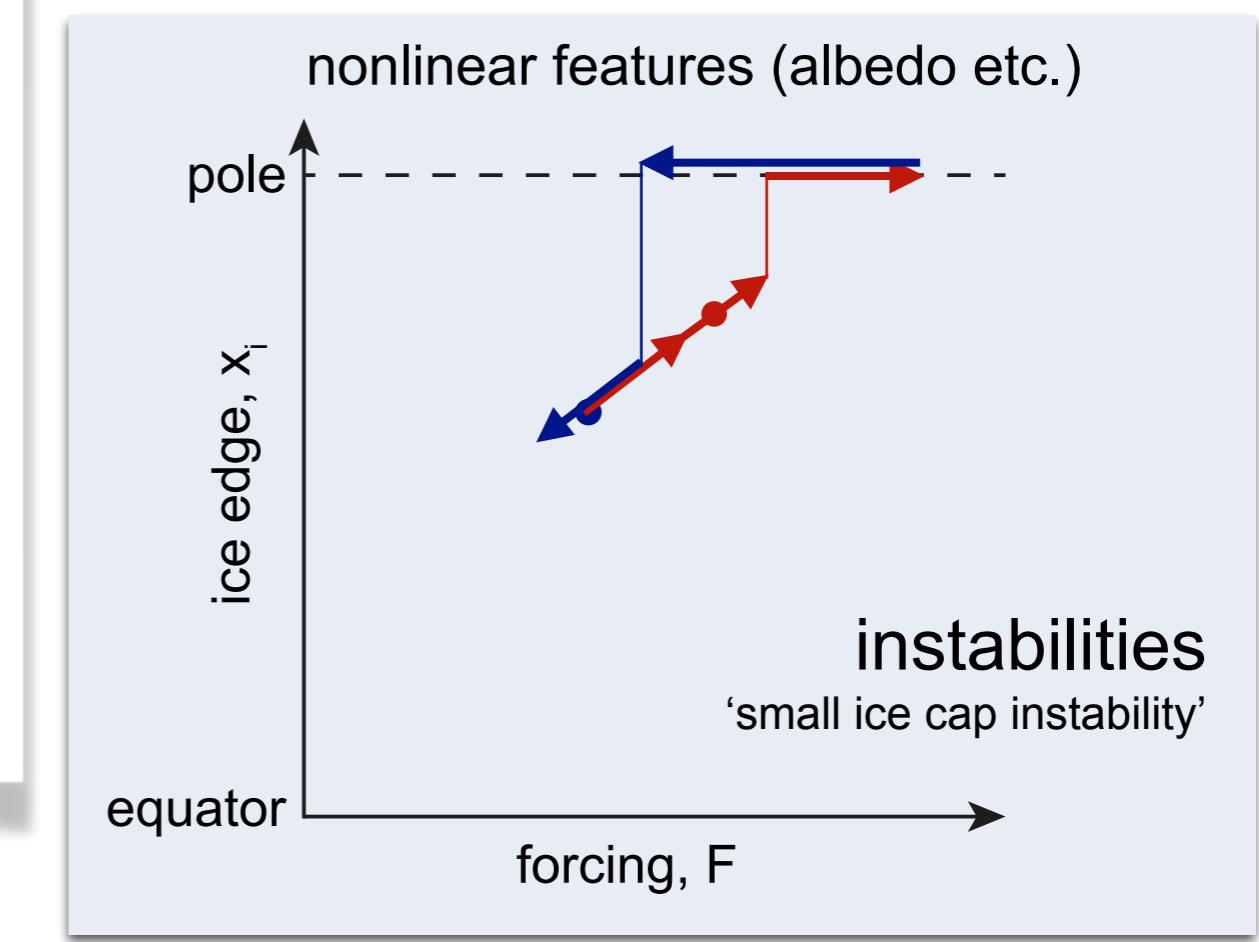
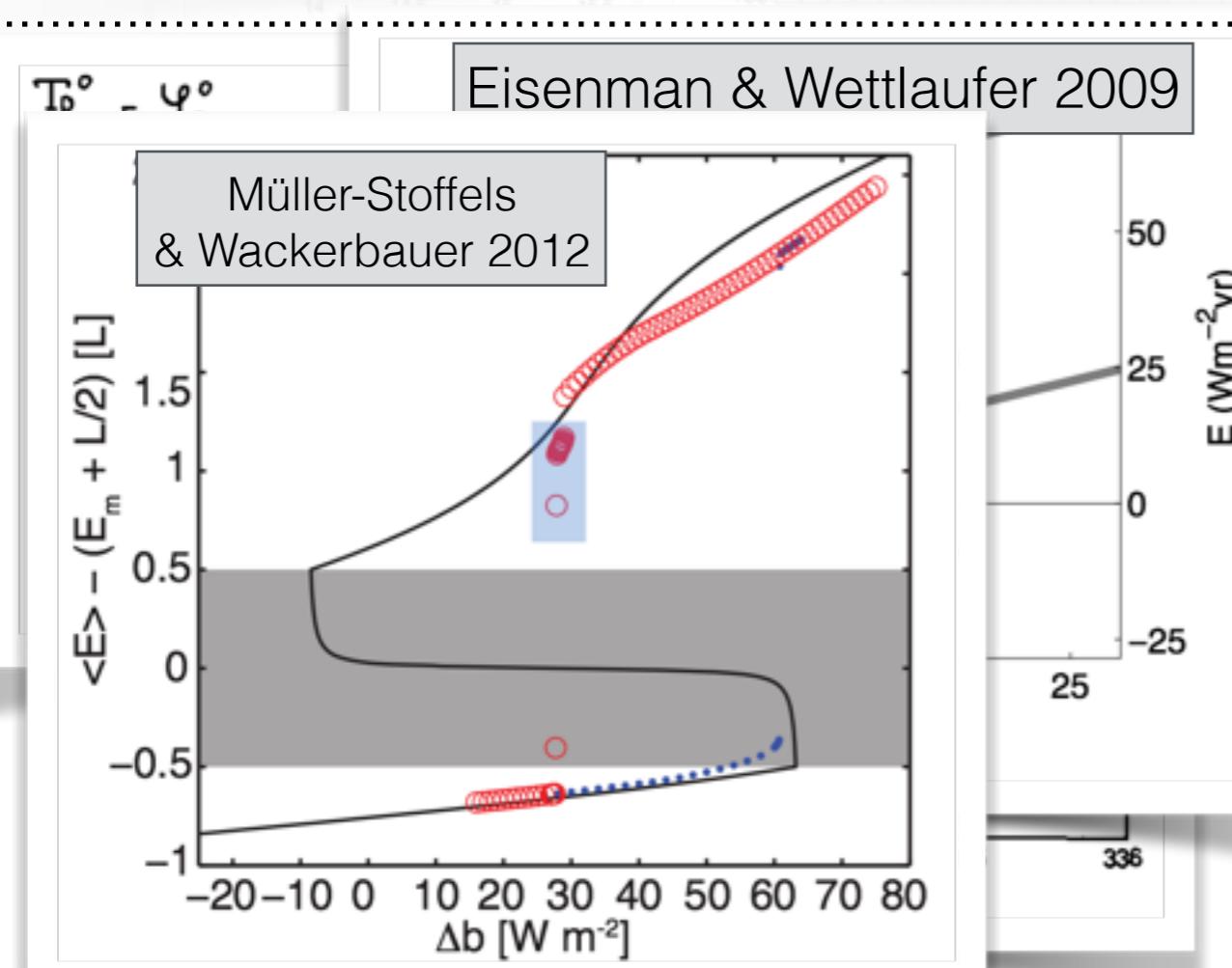
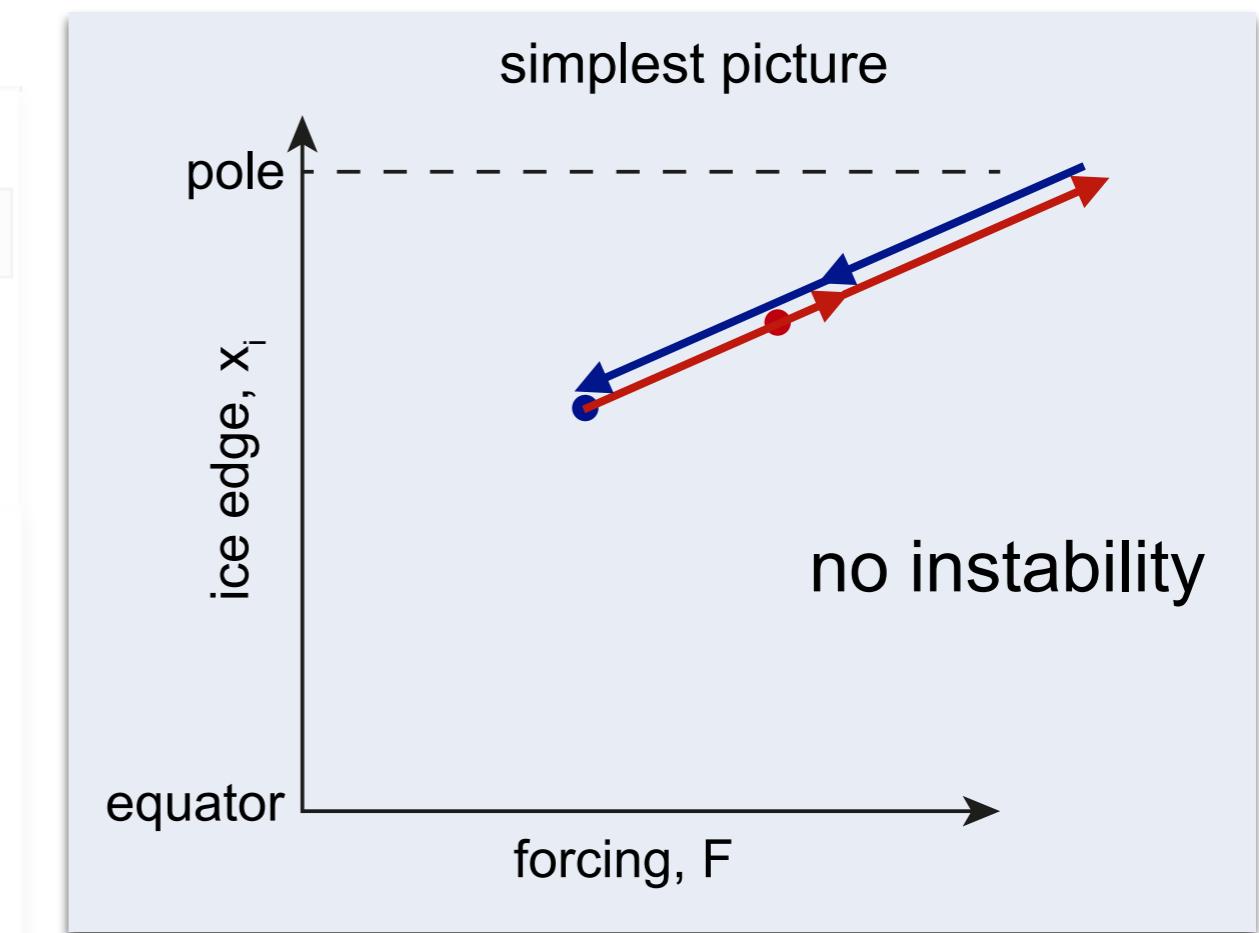
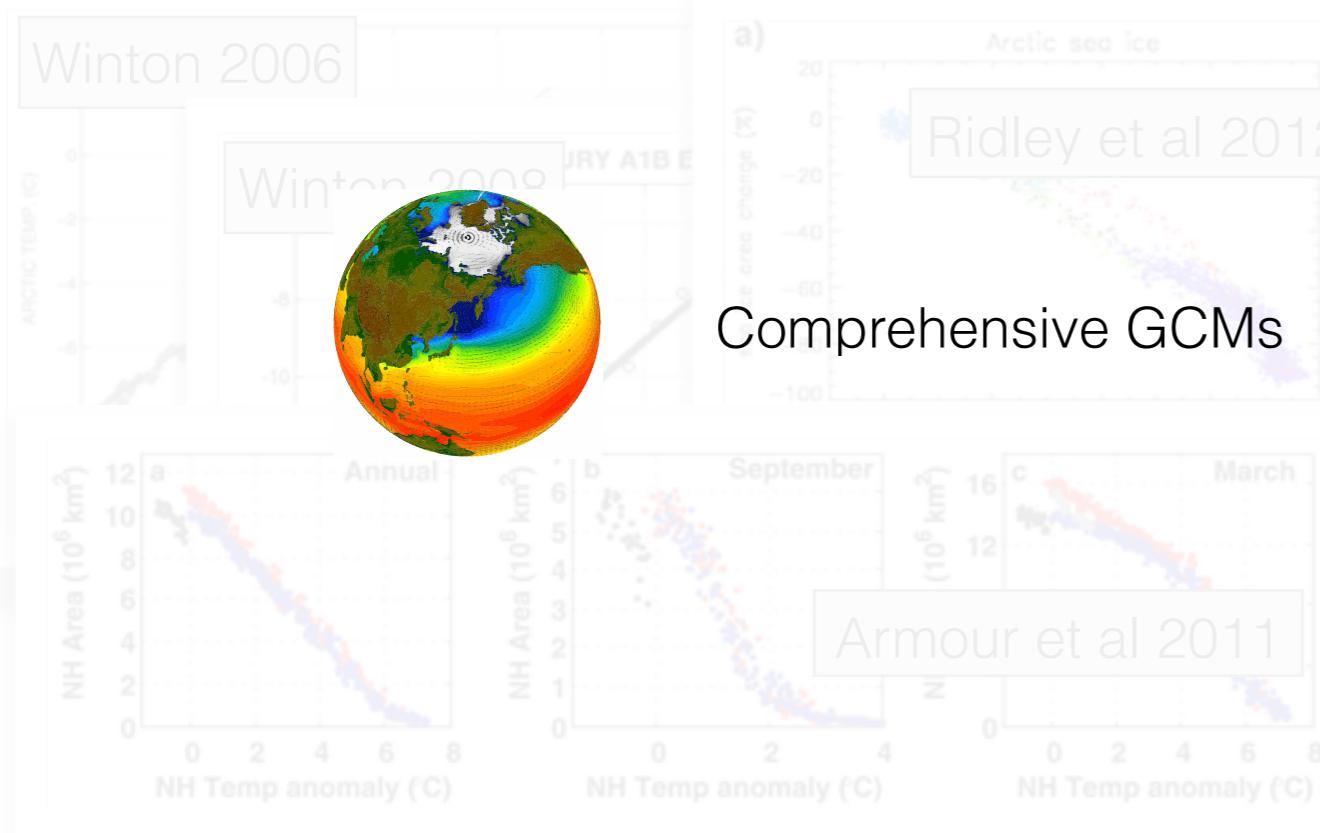
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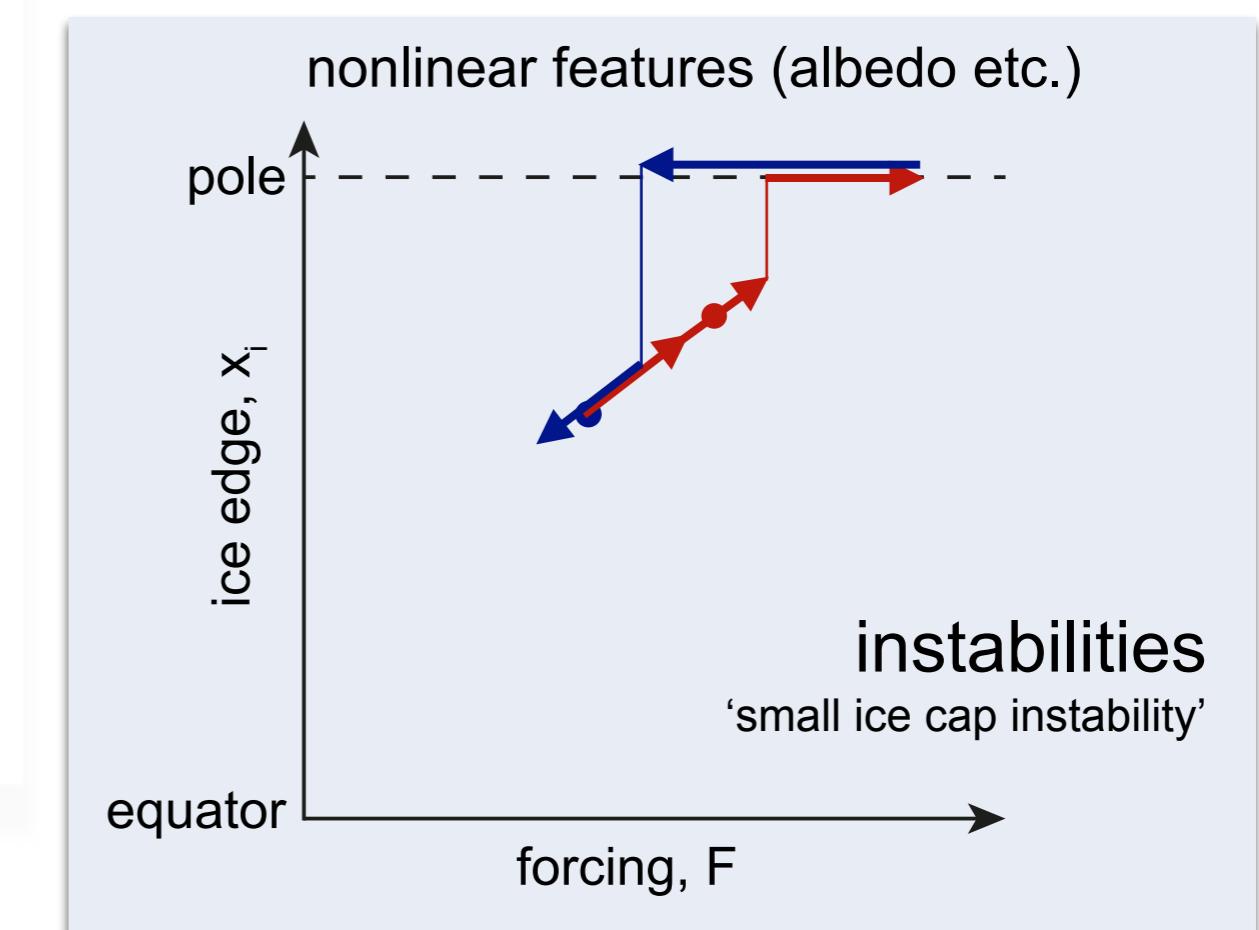
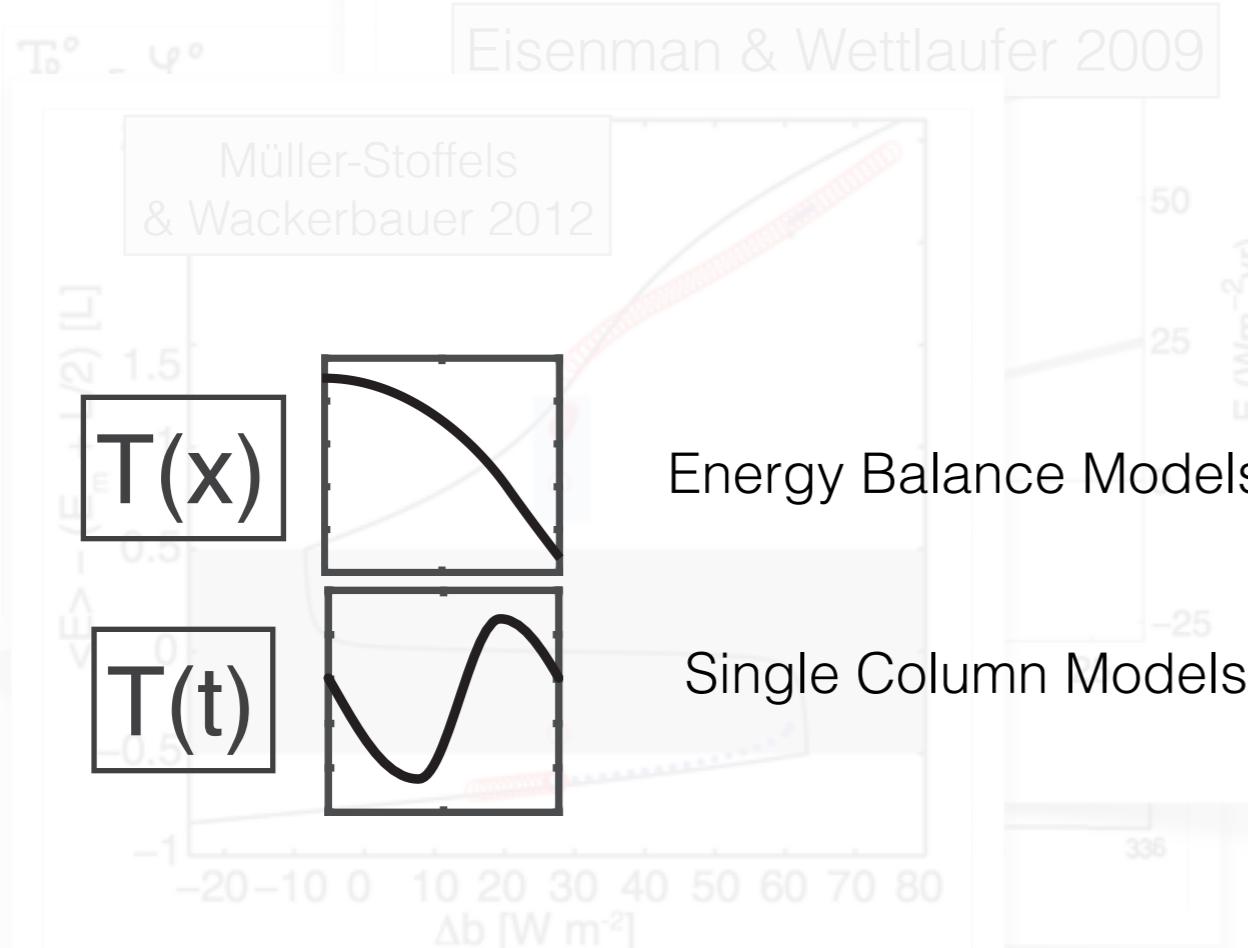
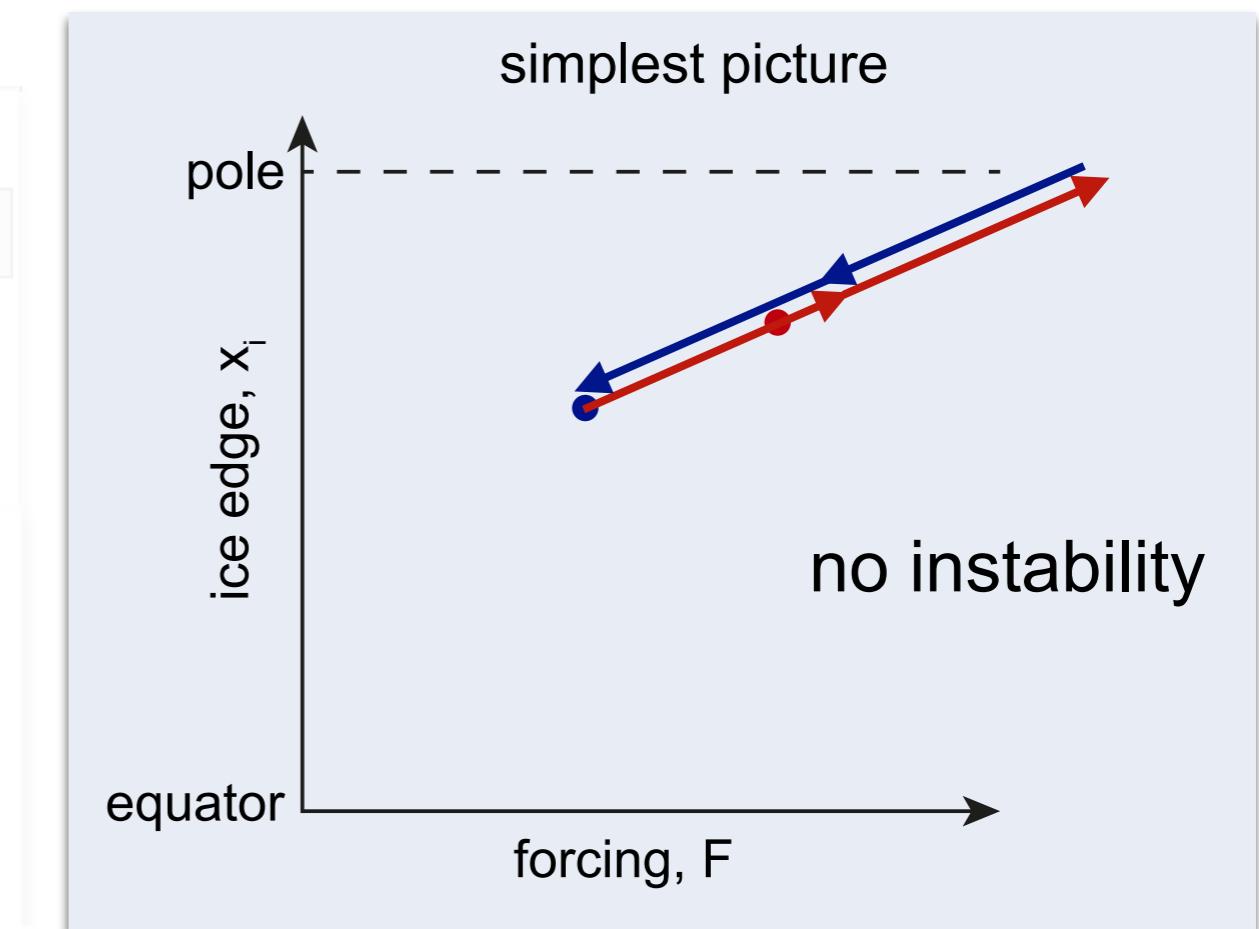
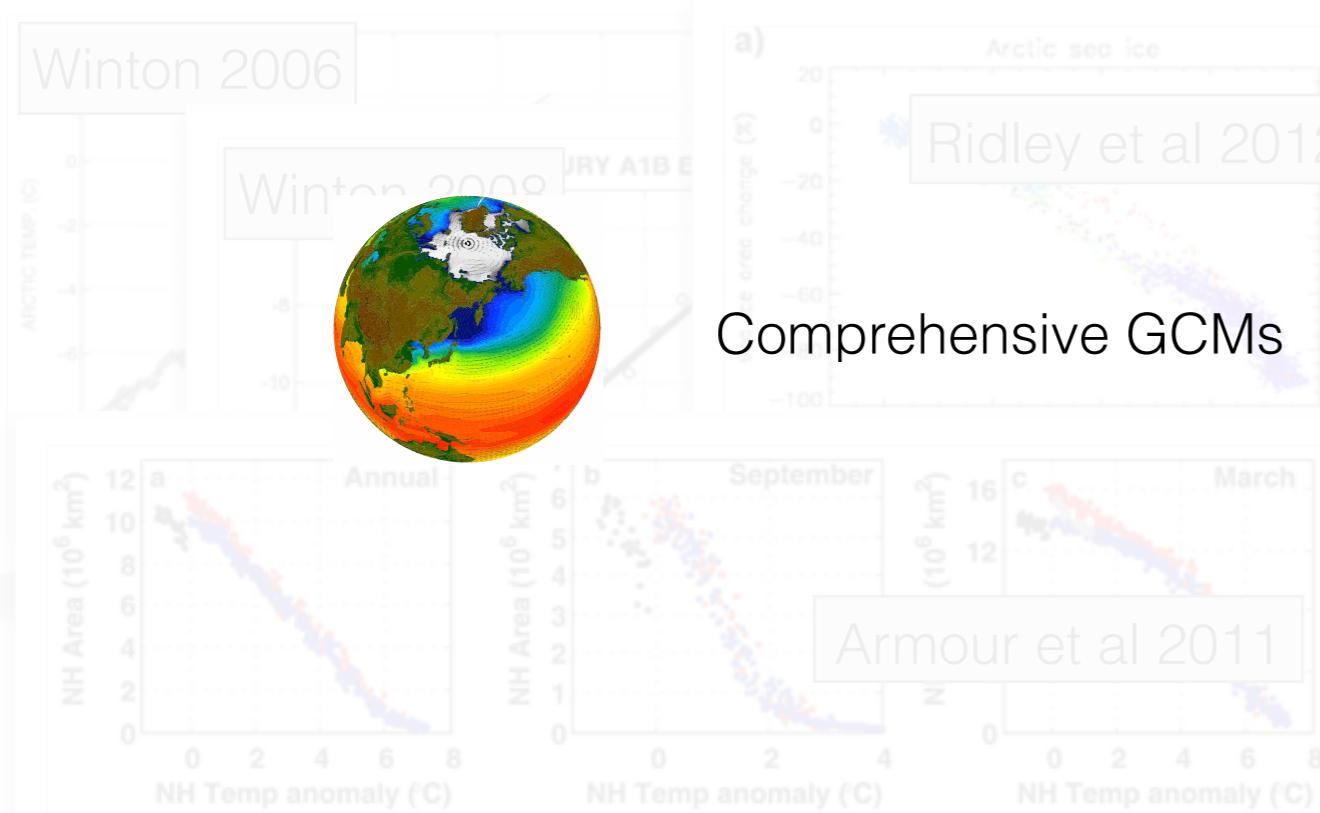
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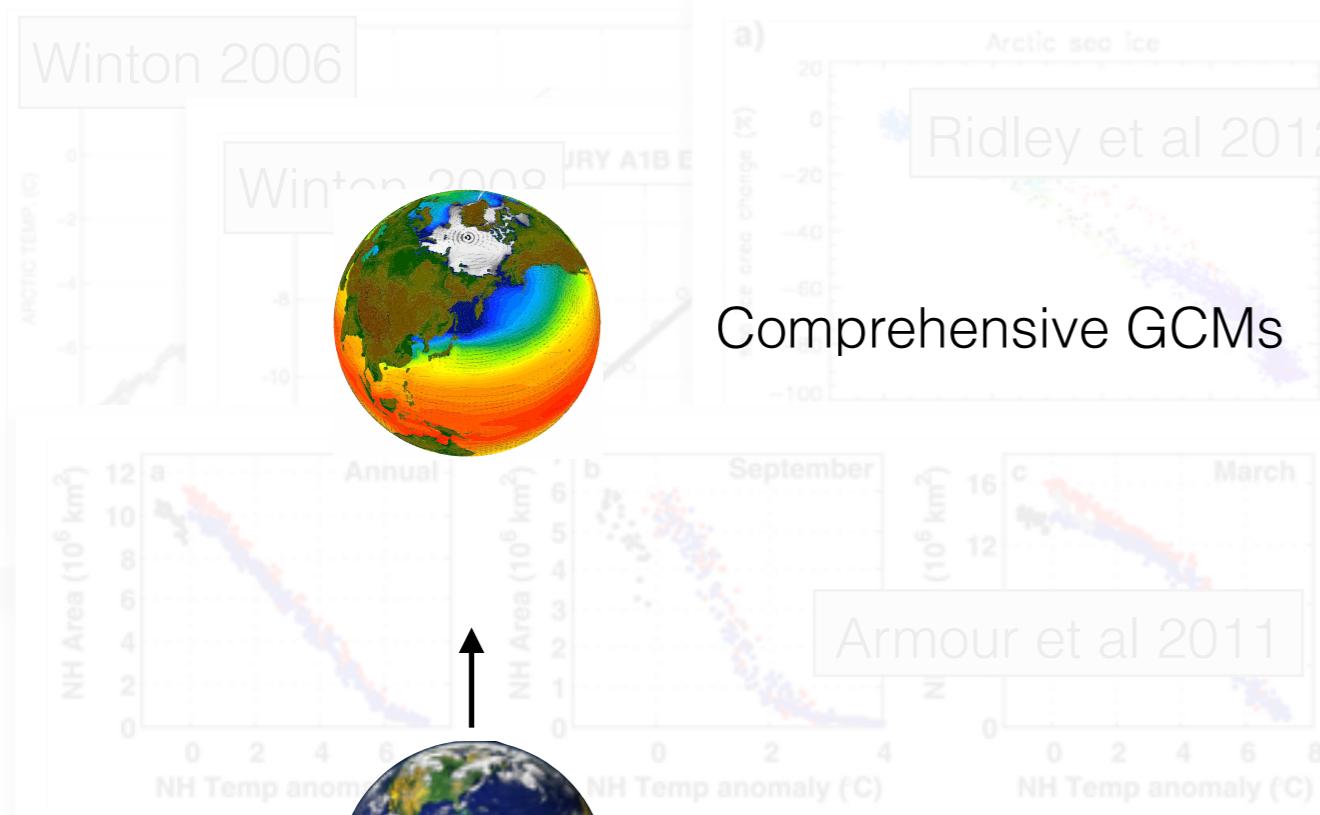
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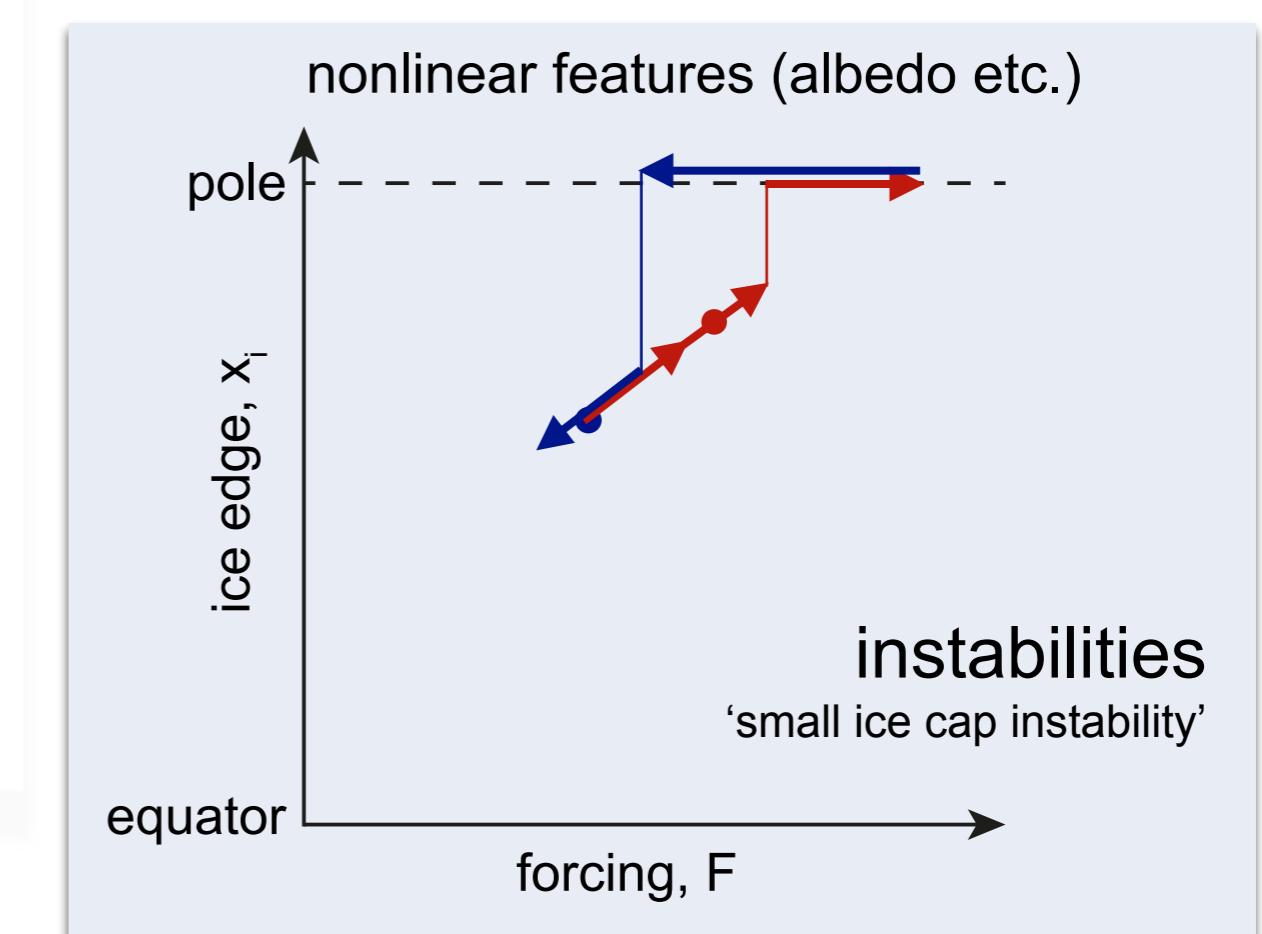
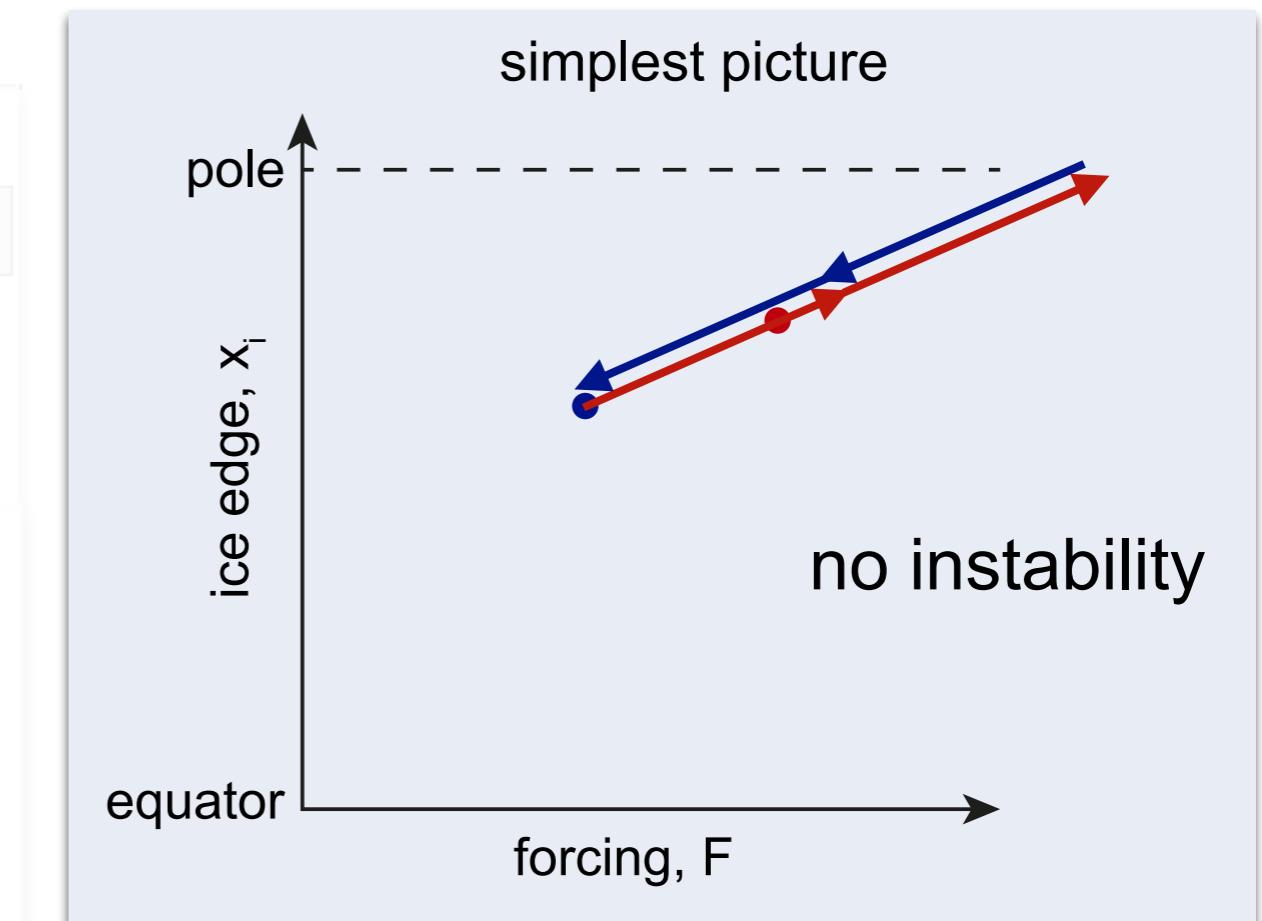
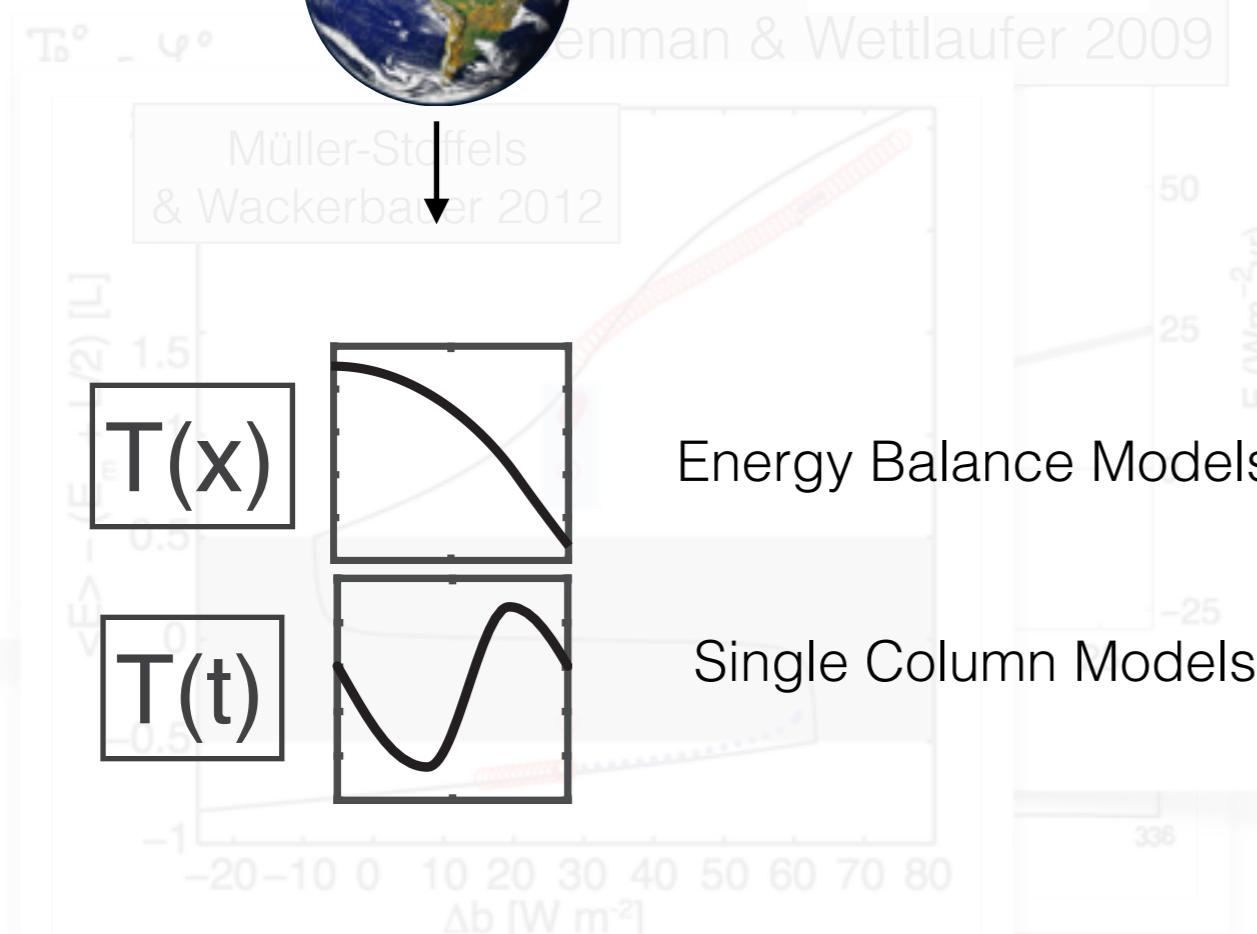
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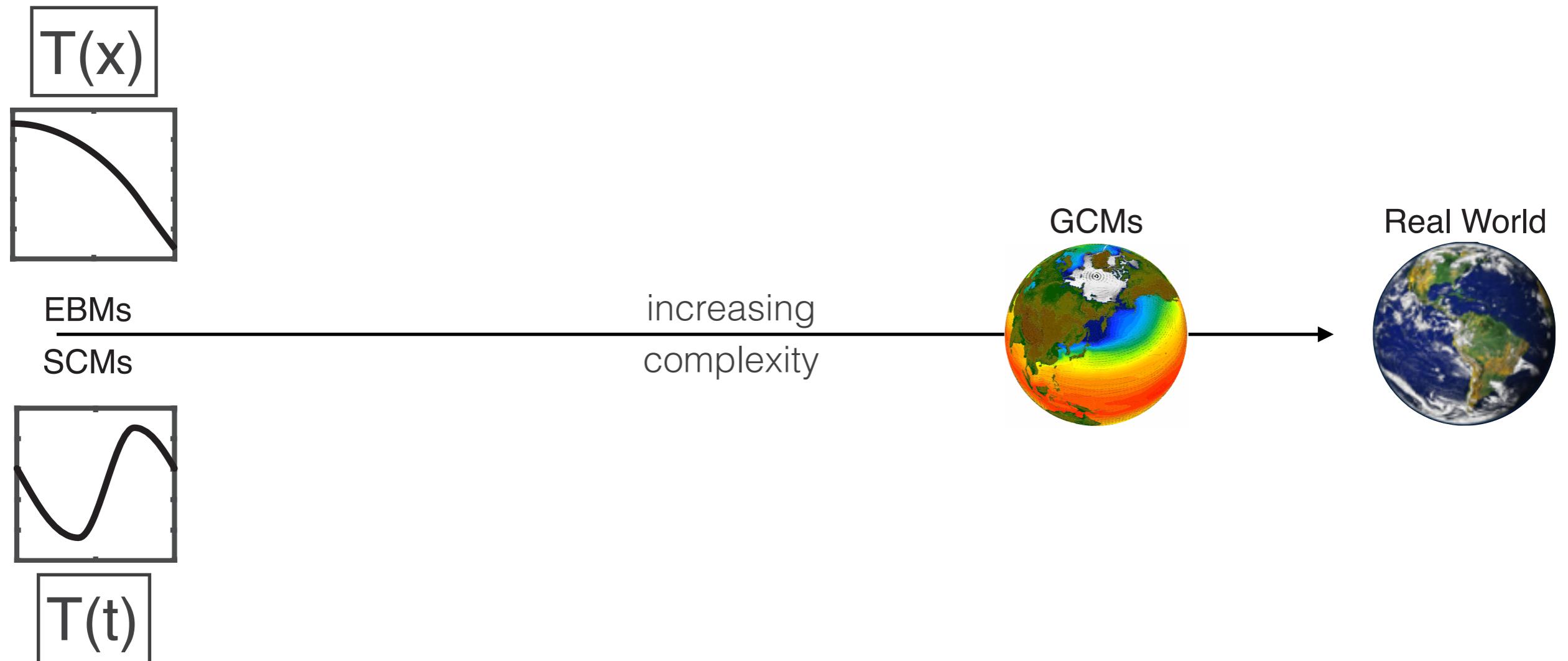


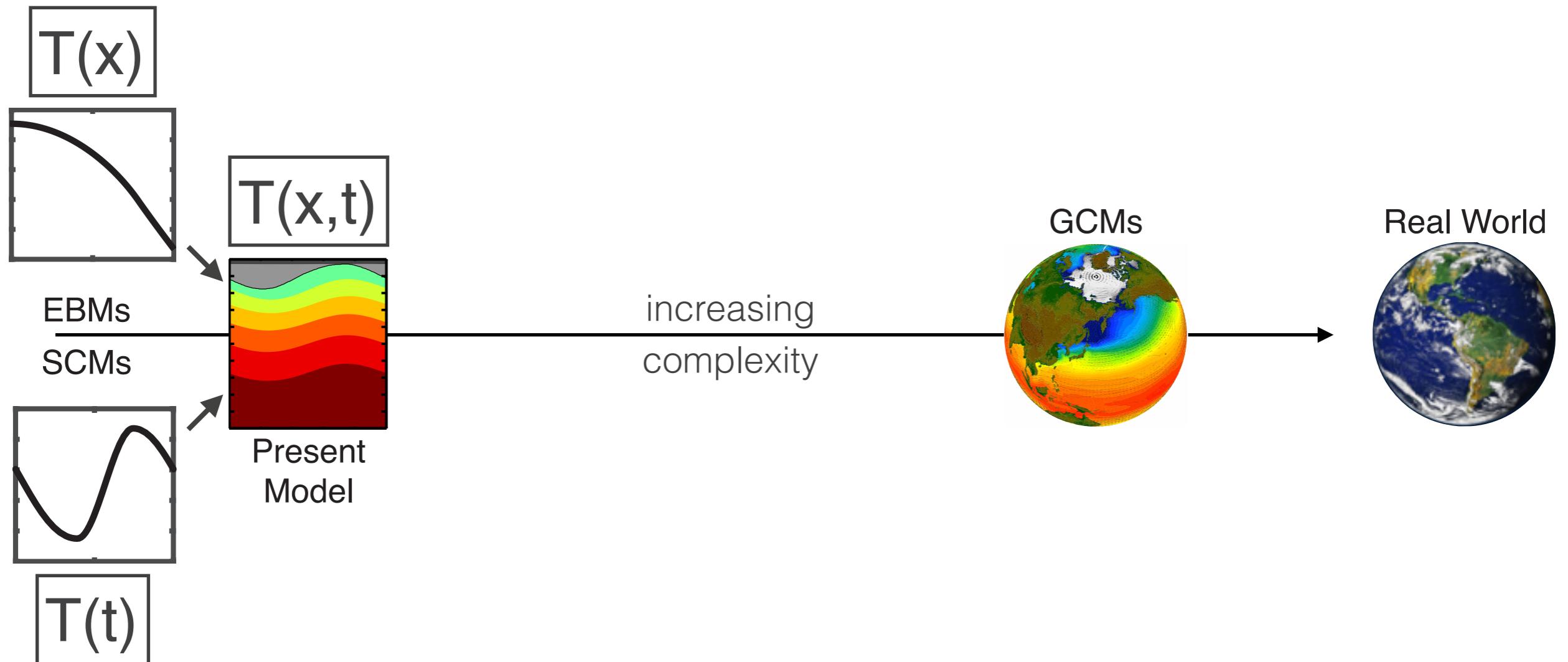
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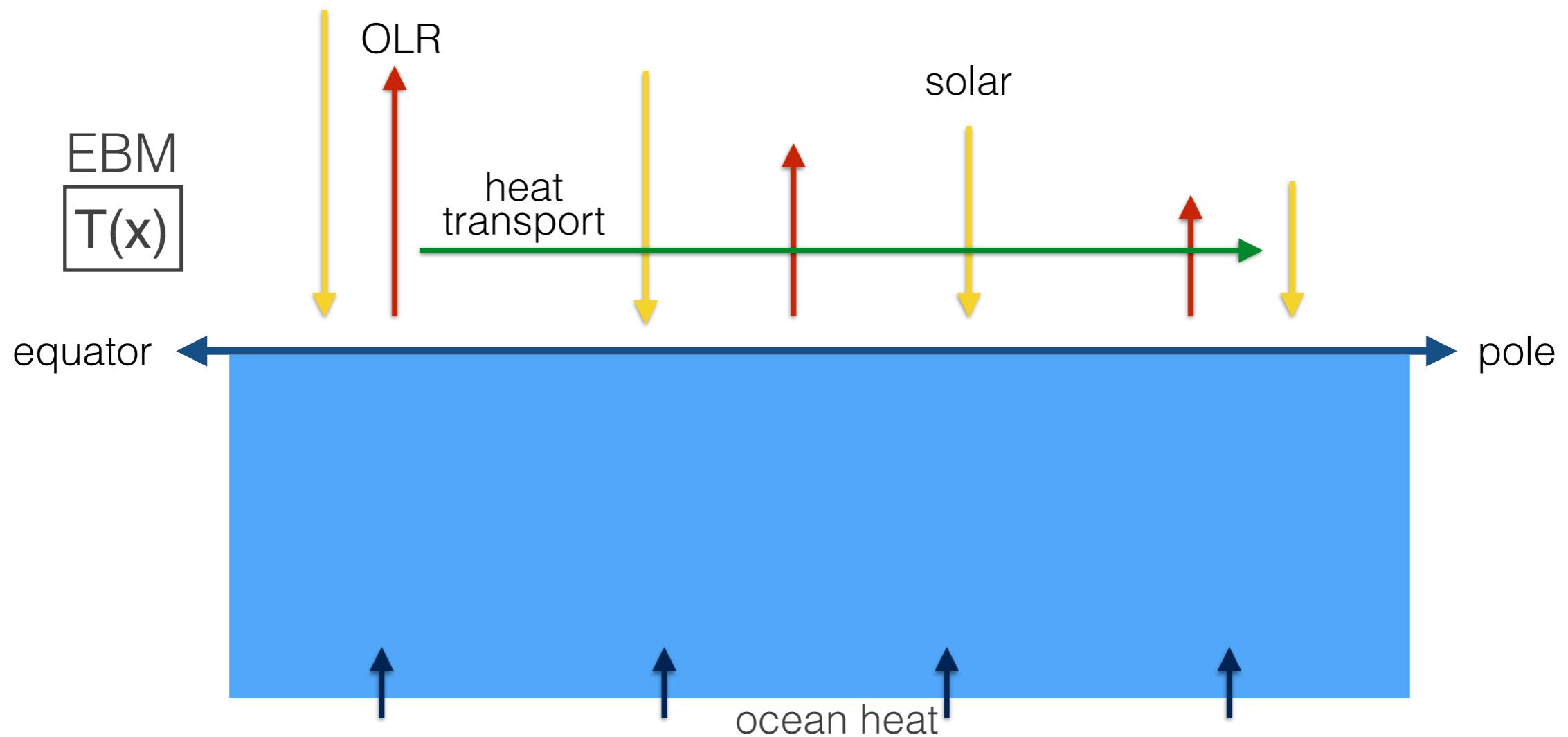


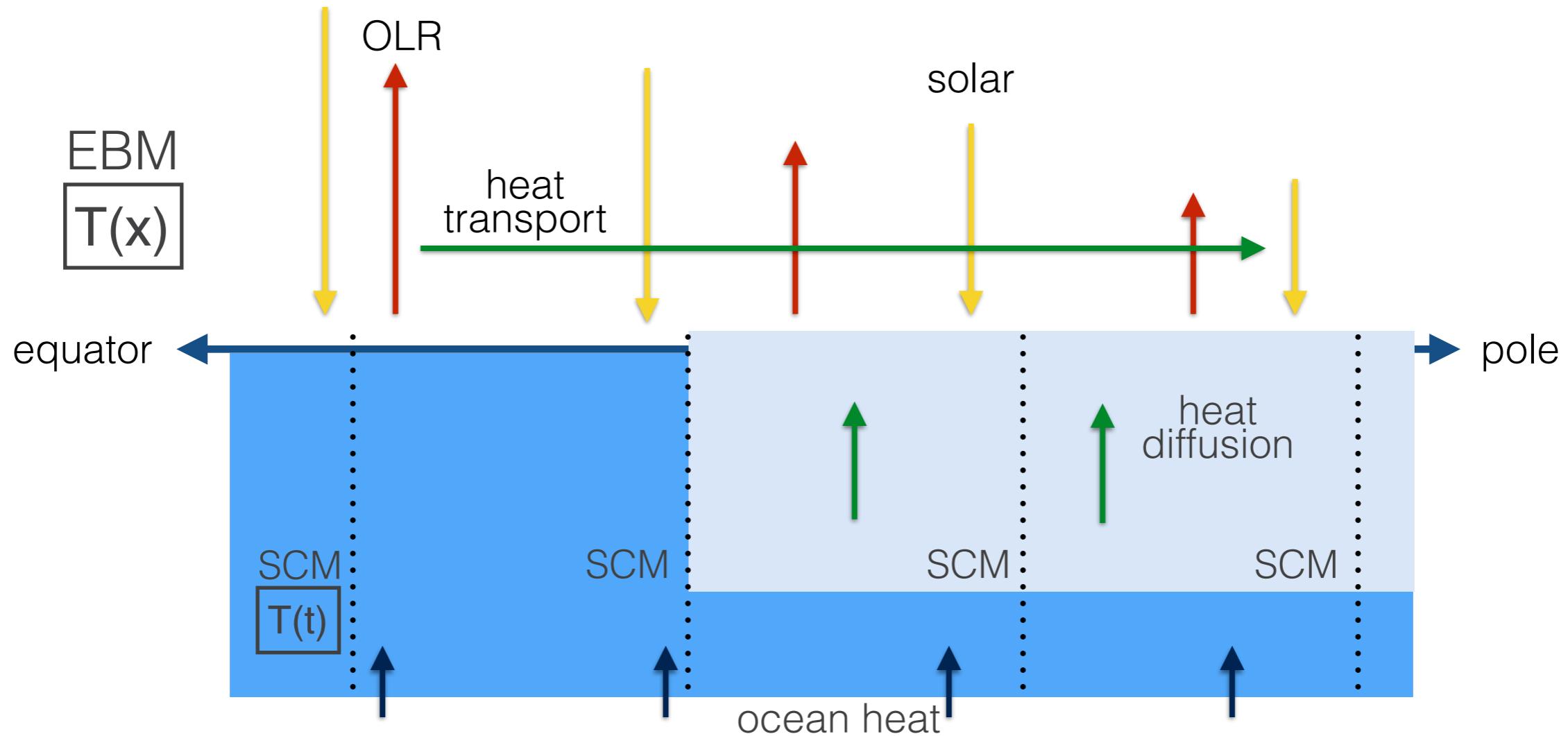
Real World ?

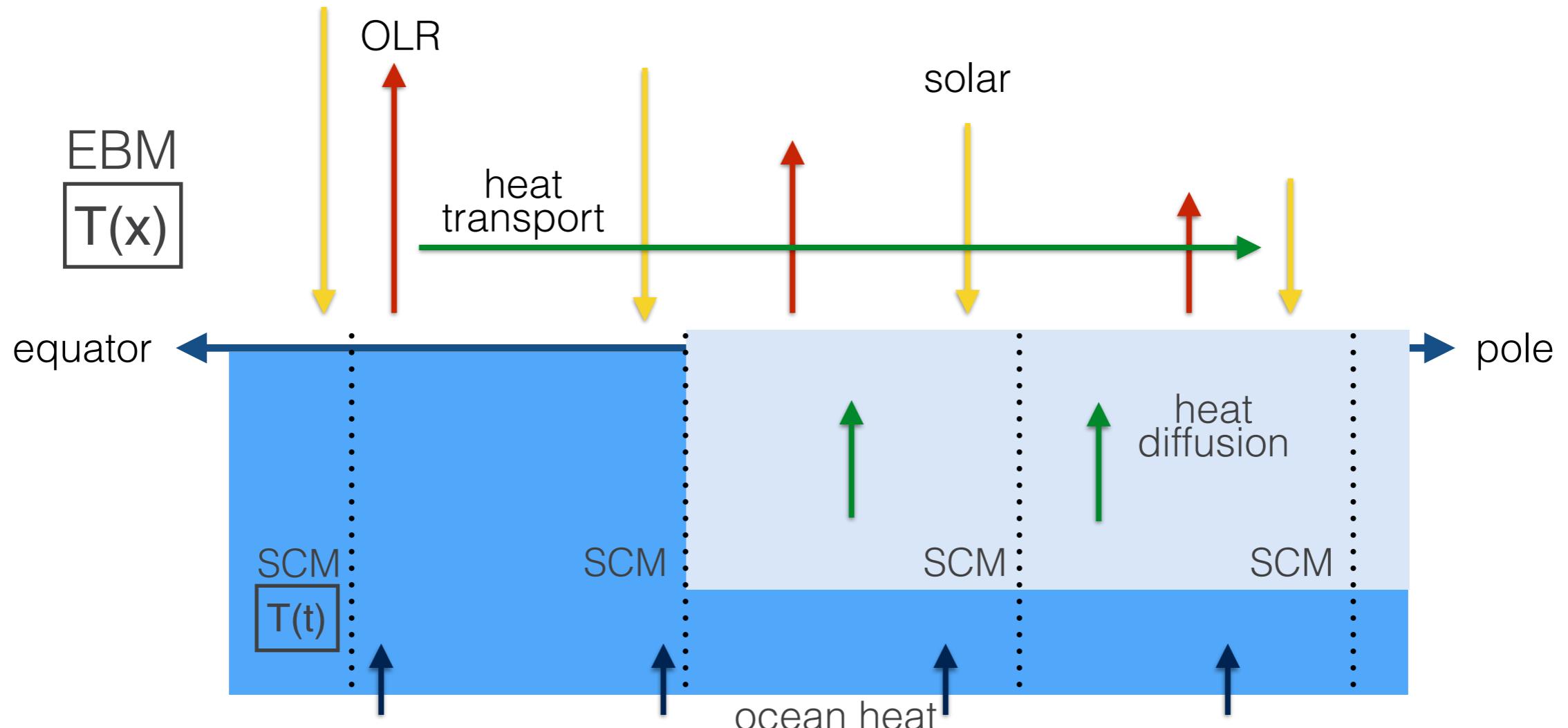




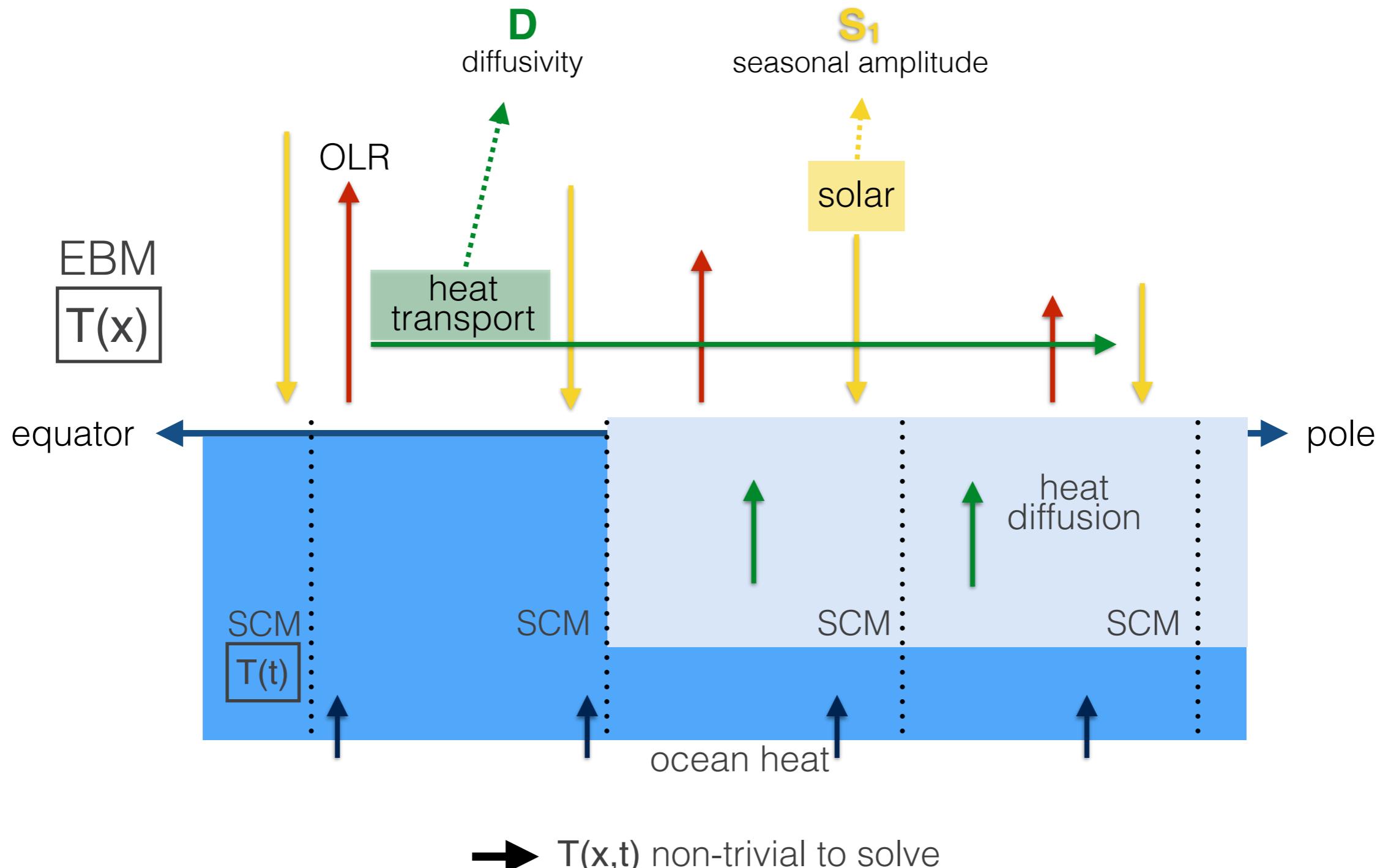


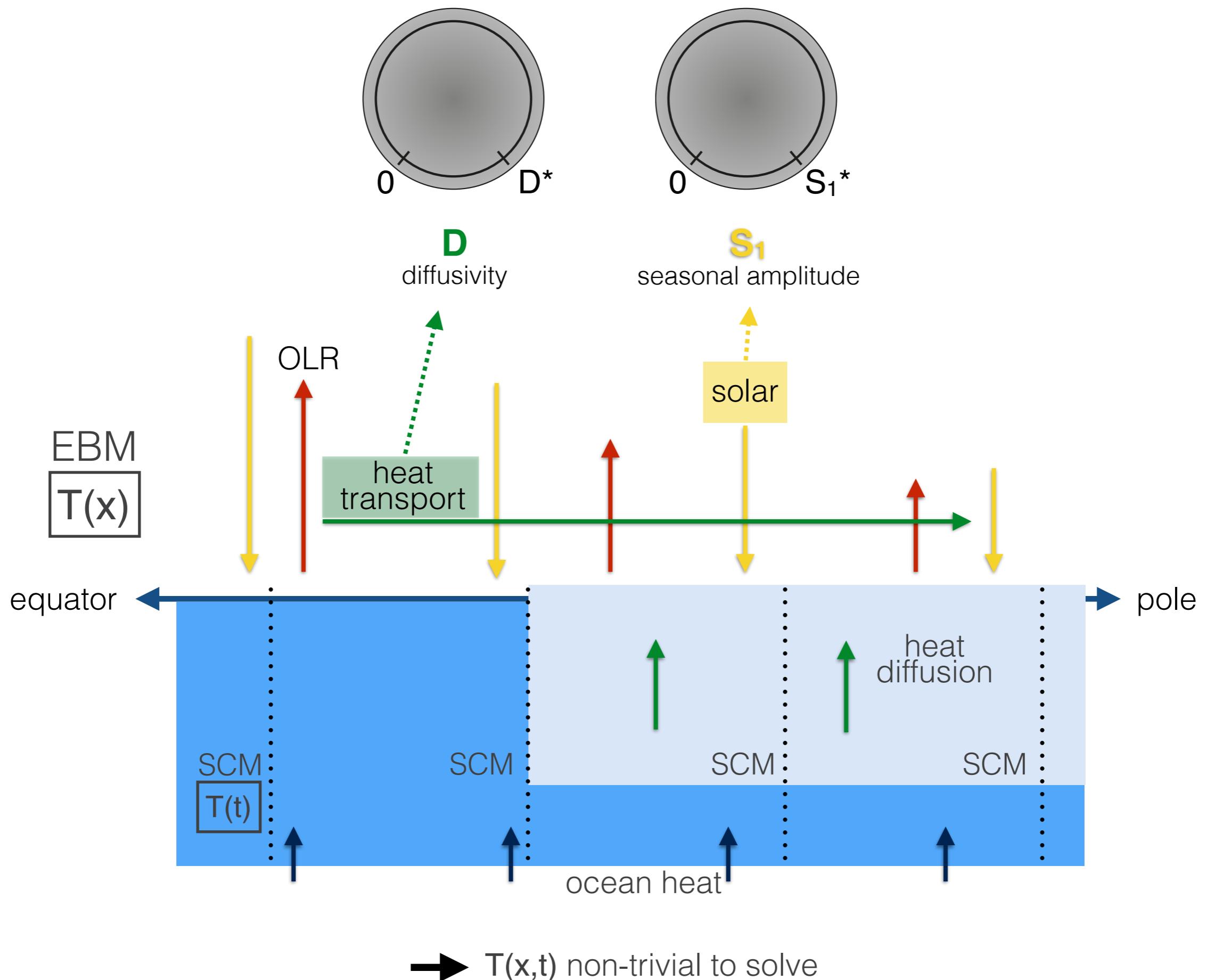




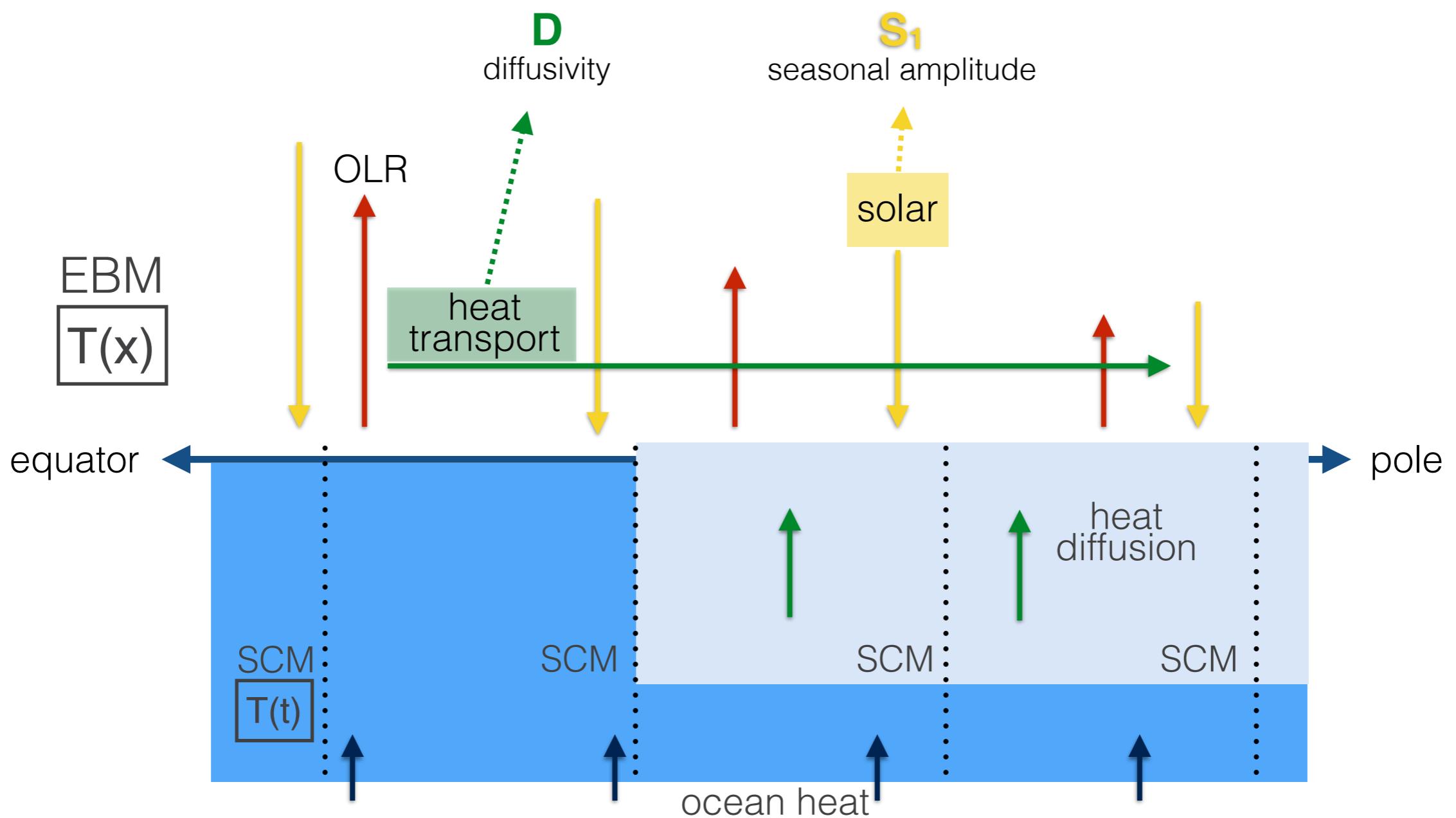
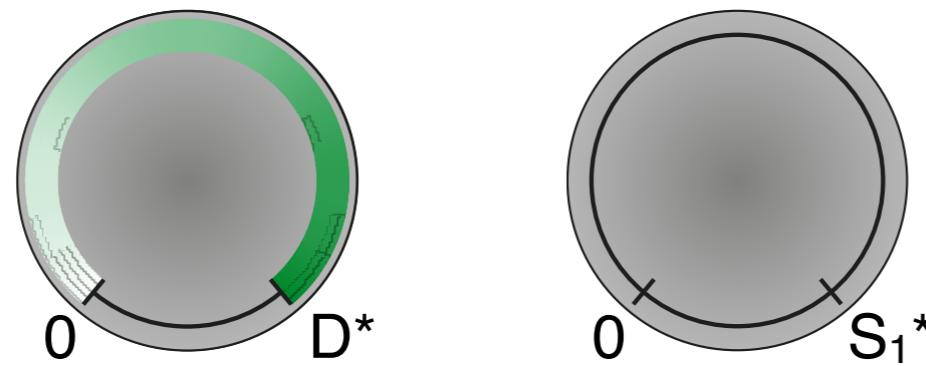


→ $T(x,t)$ non-trivial to solve



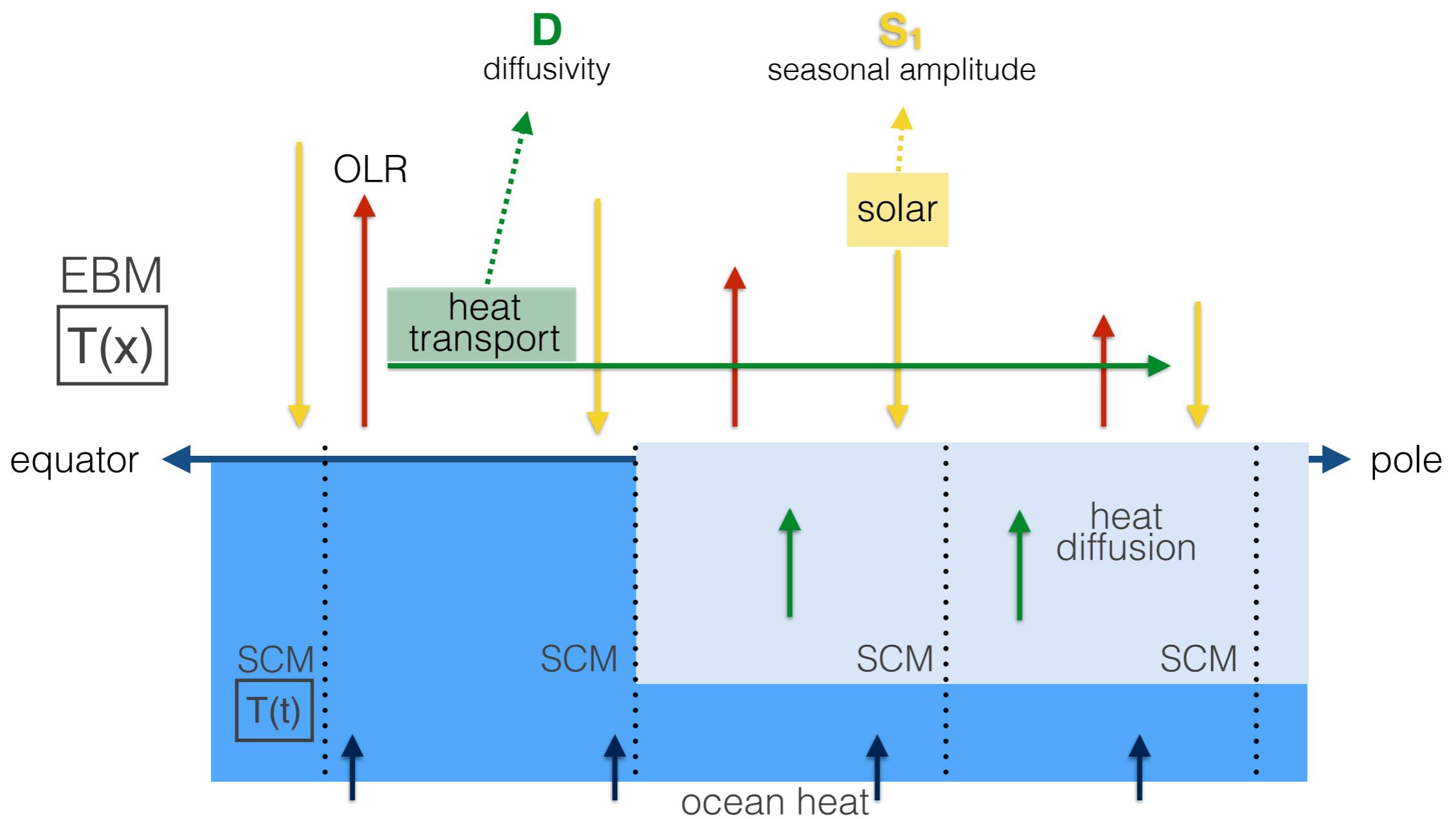
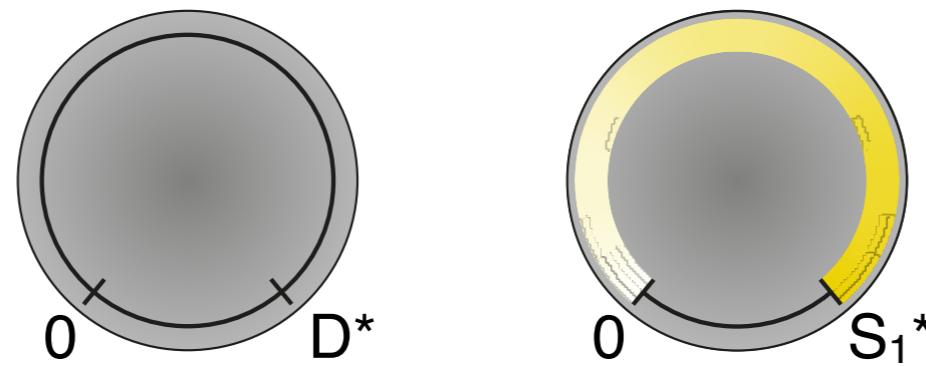


EBM



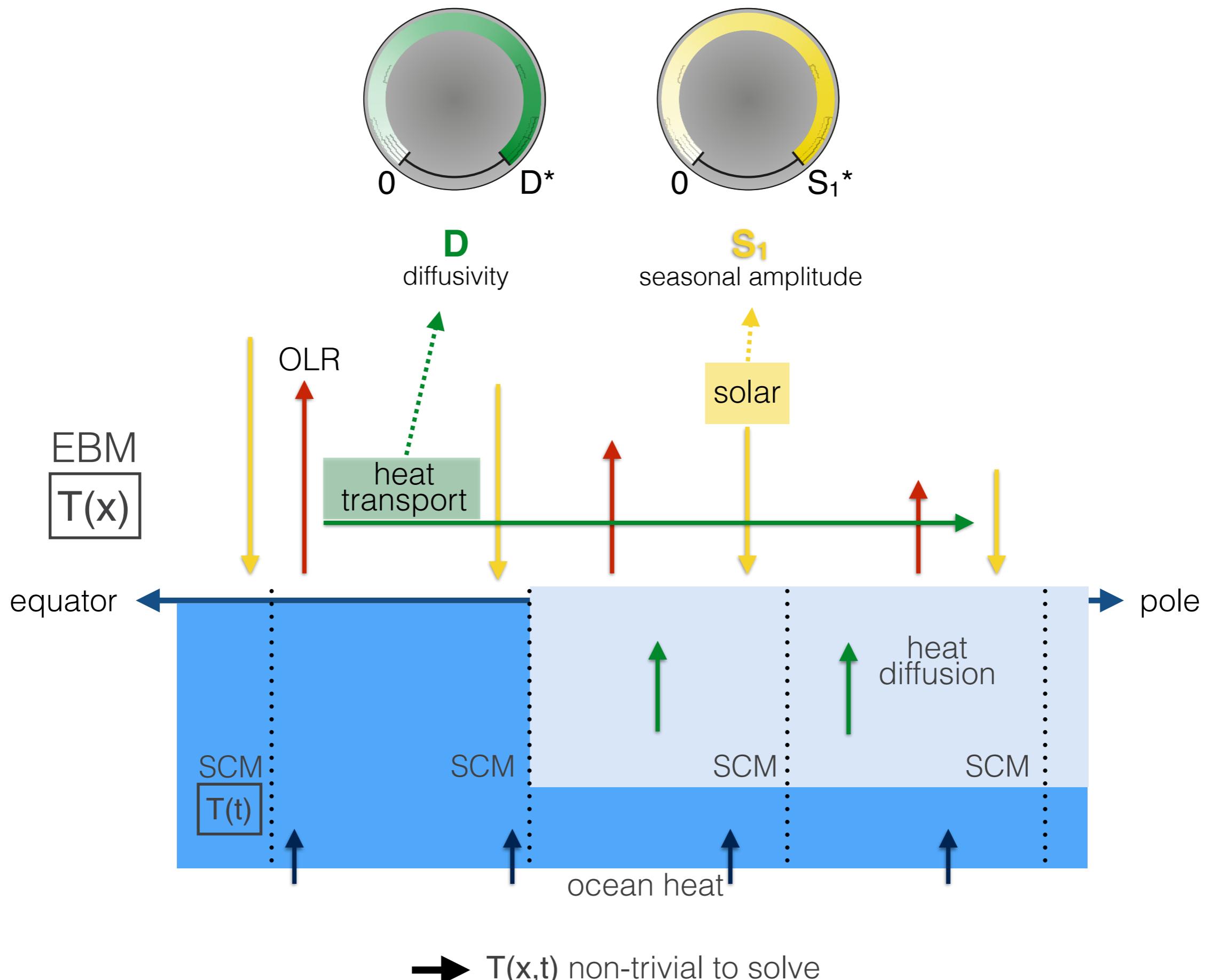
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SCM

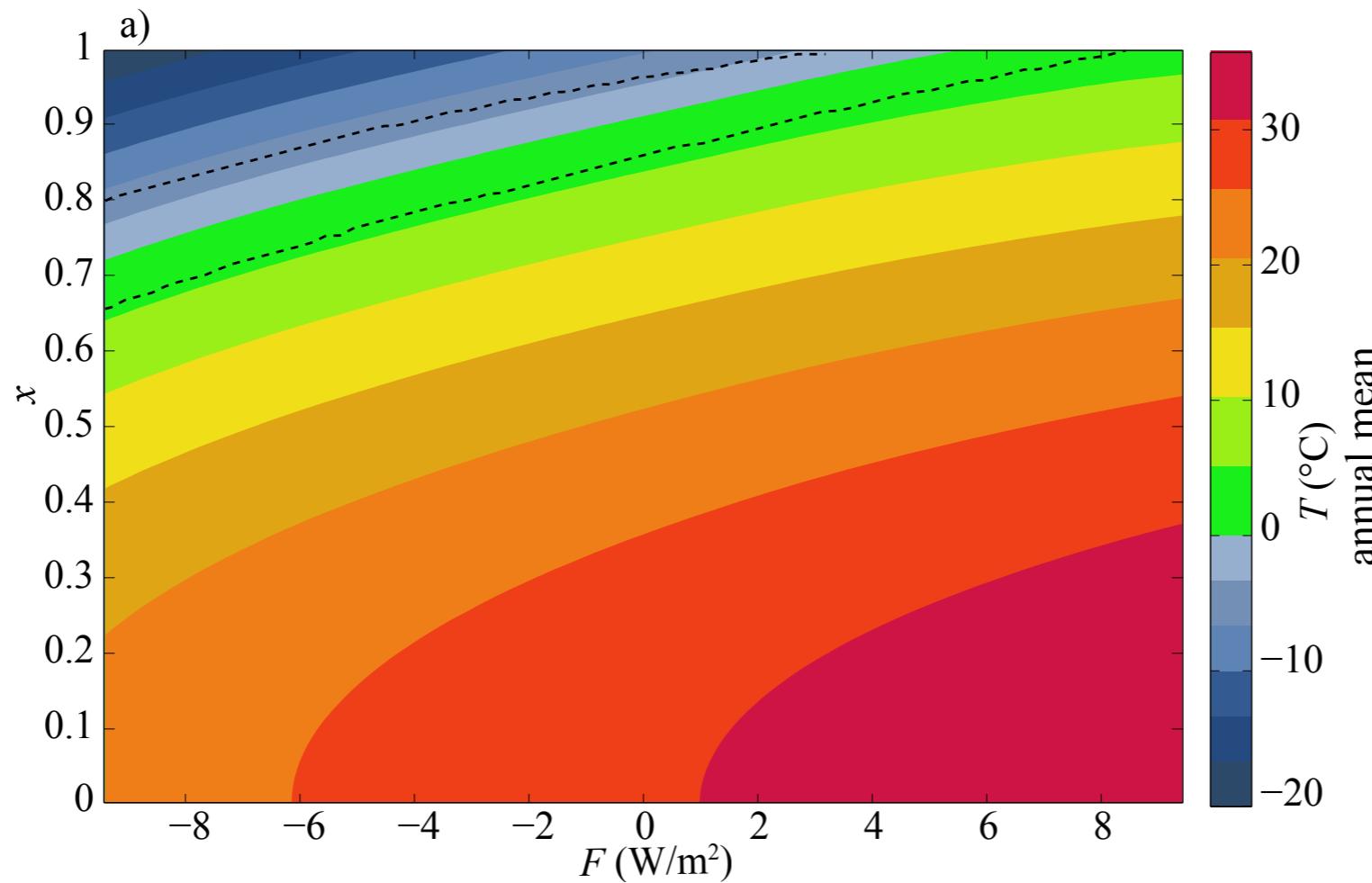
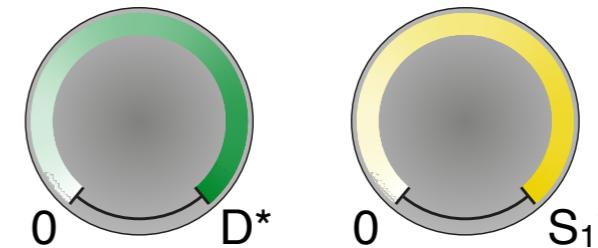


→ $T(x,t)$ non-trivial to solve

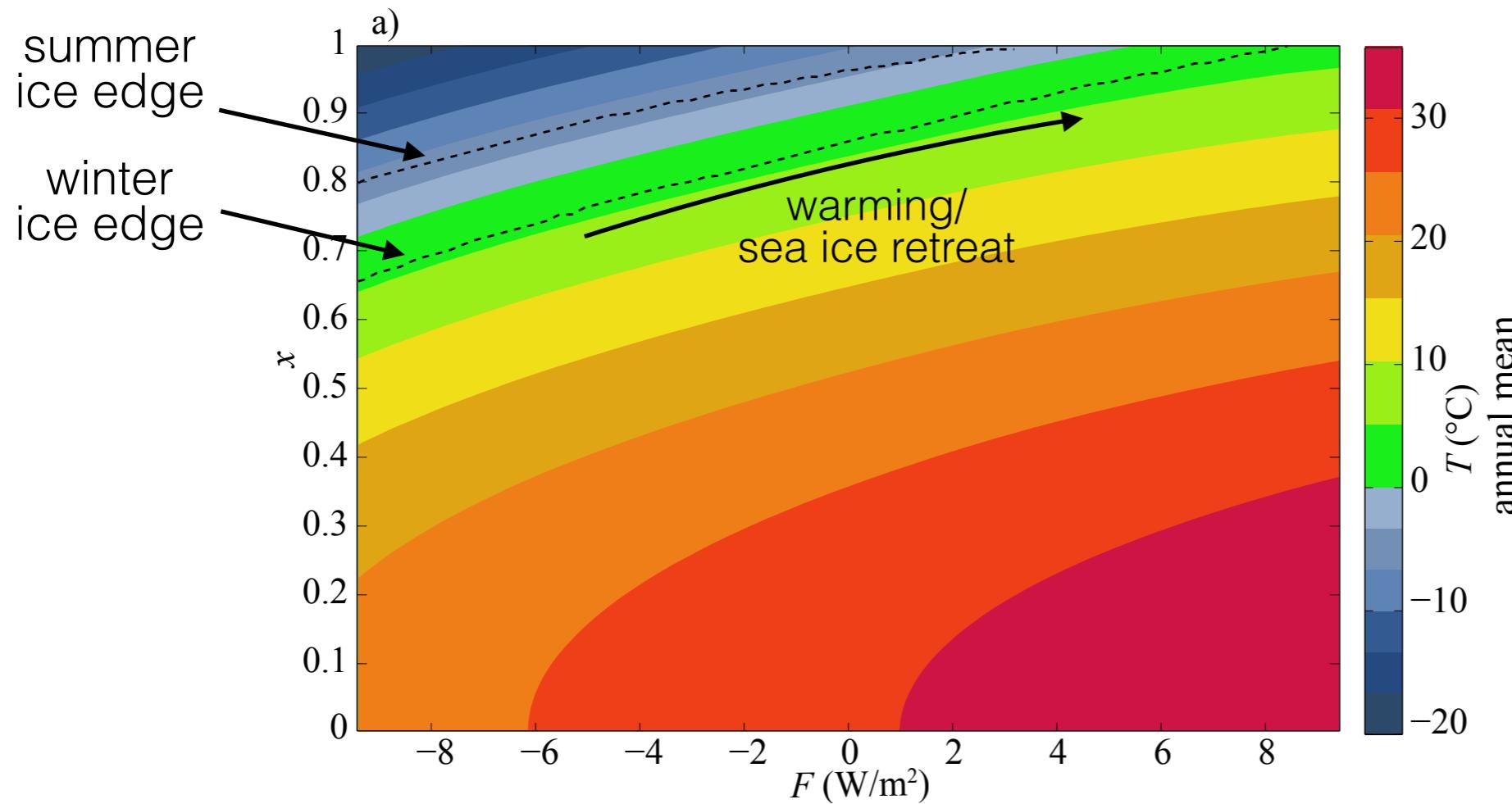
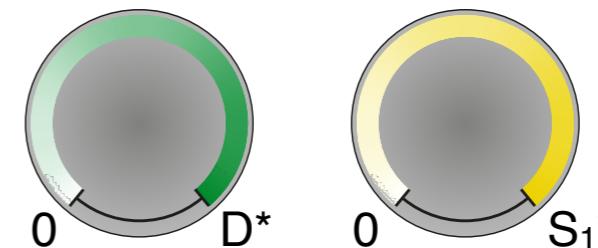
Present Model



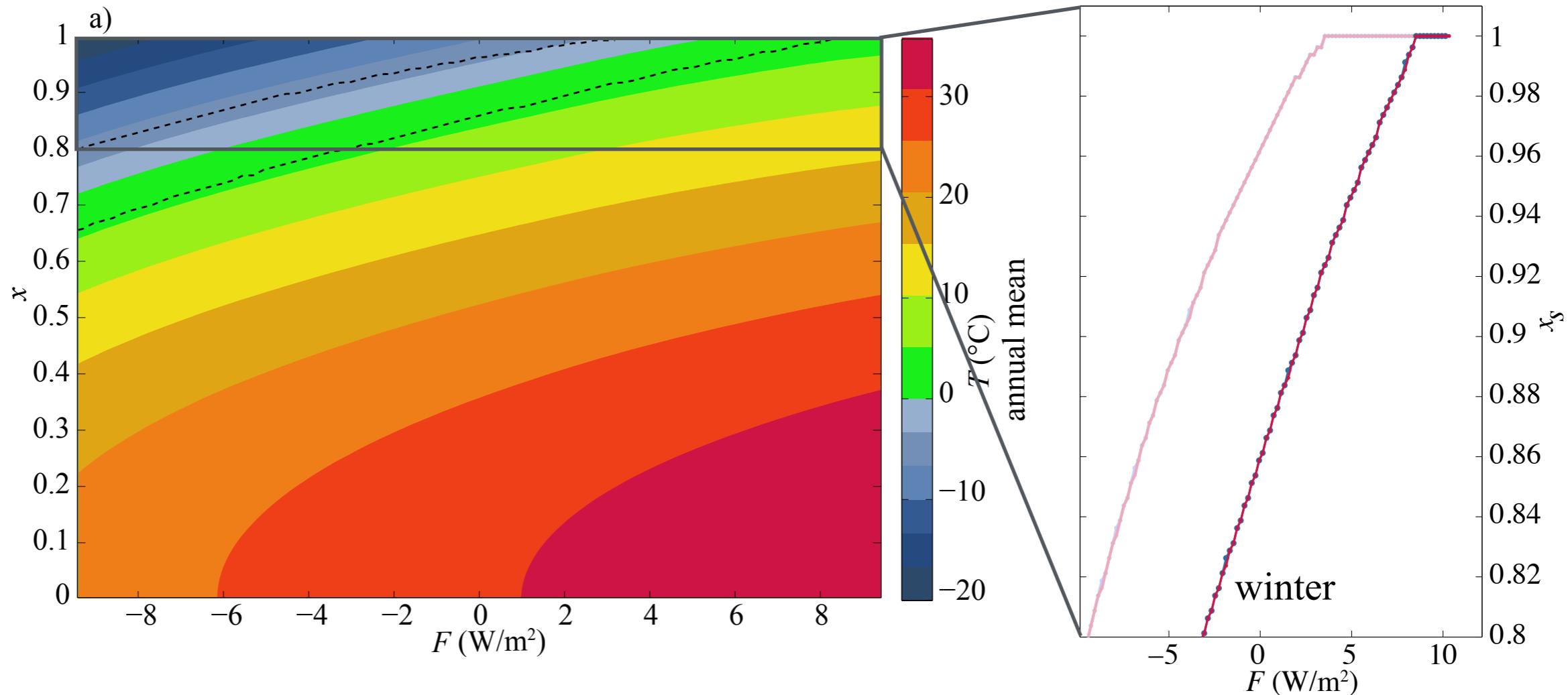
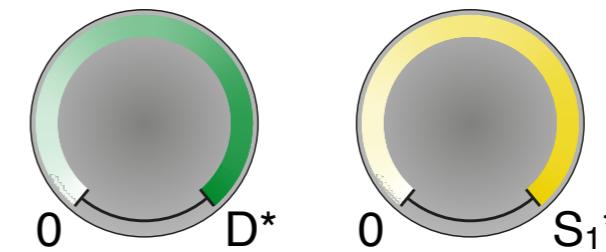
Default Model Run with global warming scenario



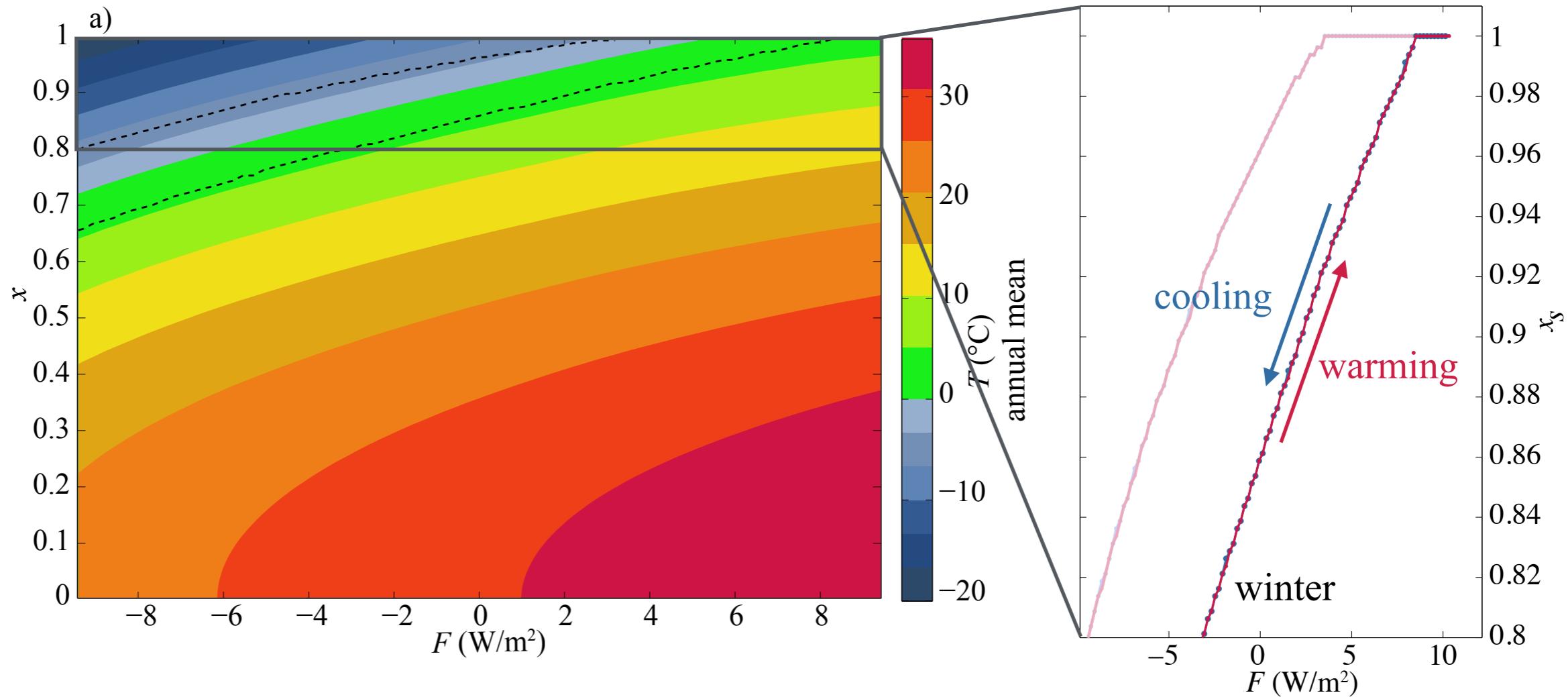
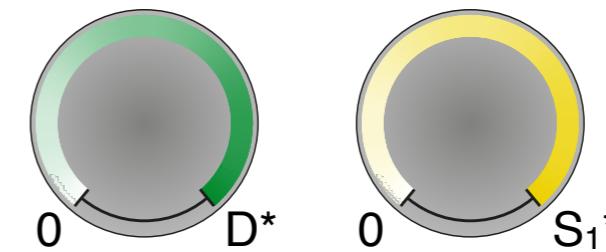
Default Model Run with global warming scenario



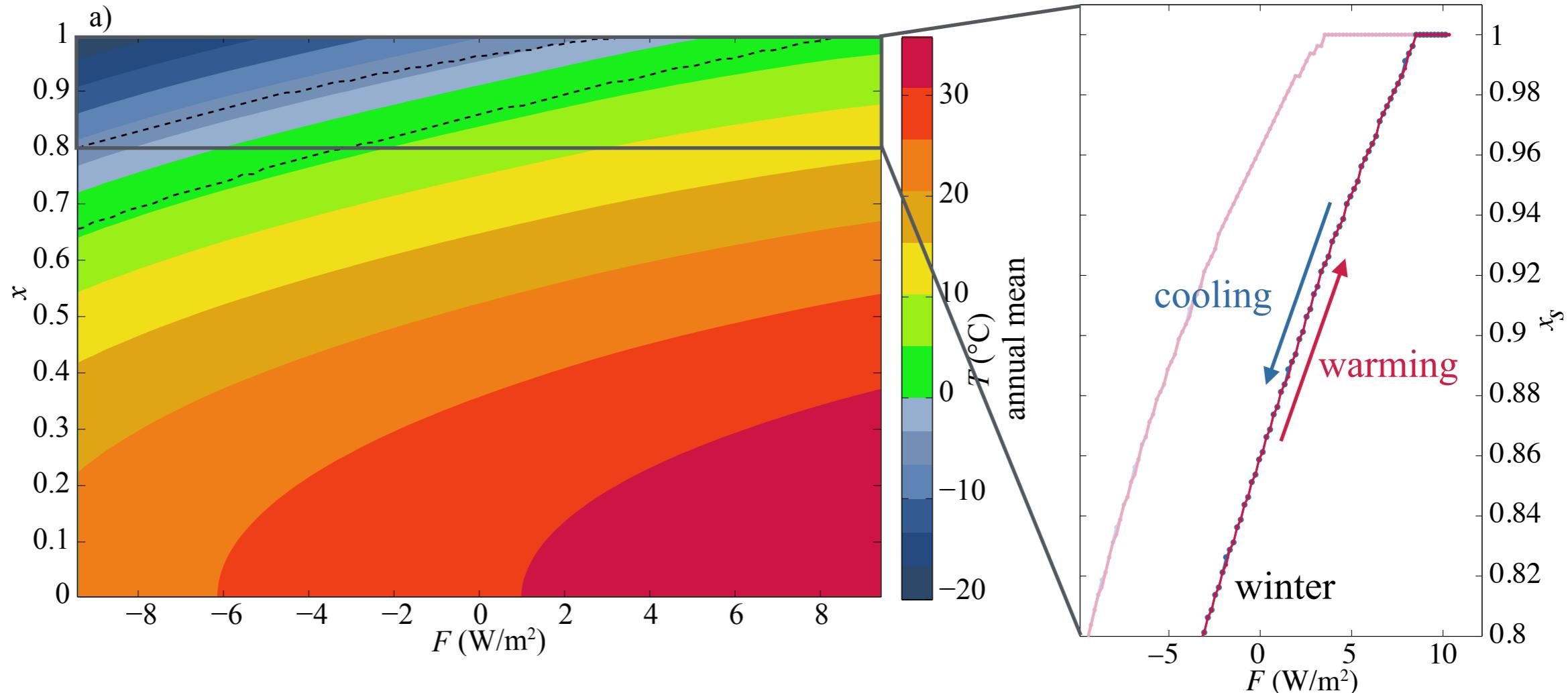
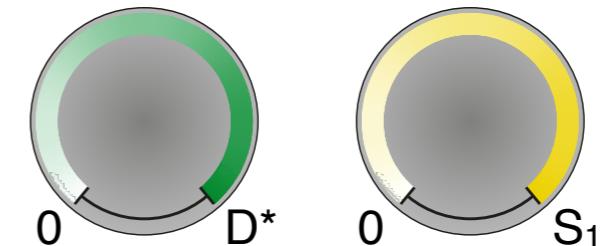
Default Model Run with global warming scenario



Default Model Run with global warming scenario



Default Model Run with global warming scenario



→ no instabilities
in this model!
($D=D^*$, $S_1=S_1^*$)

$\not\rightarrow$ $D=0$ (SCM),
 $S_1=0$ (EBM),
both have instabilities

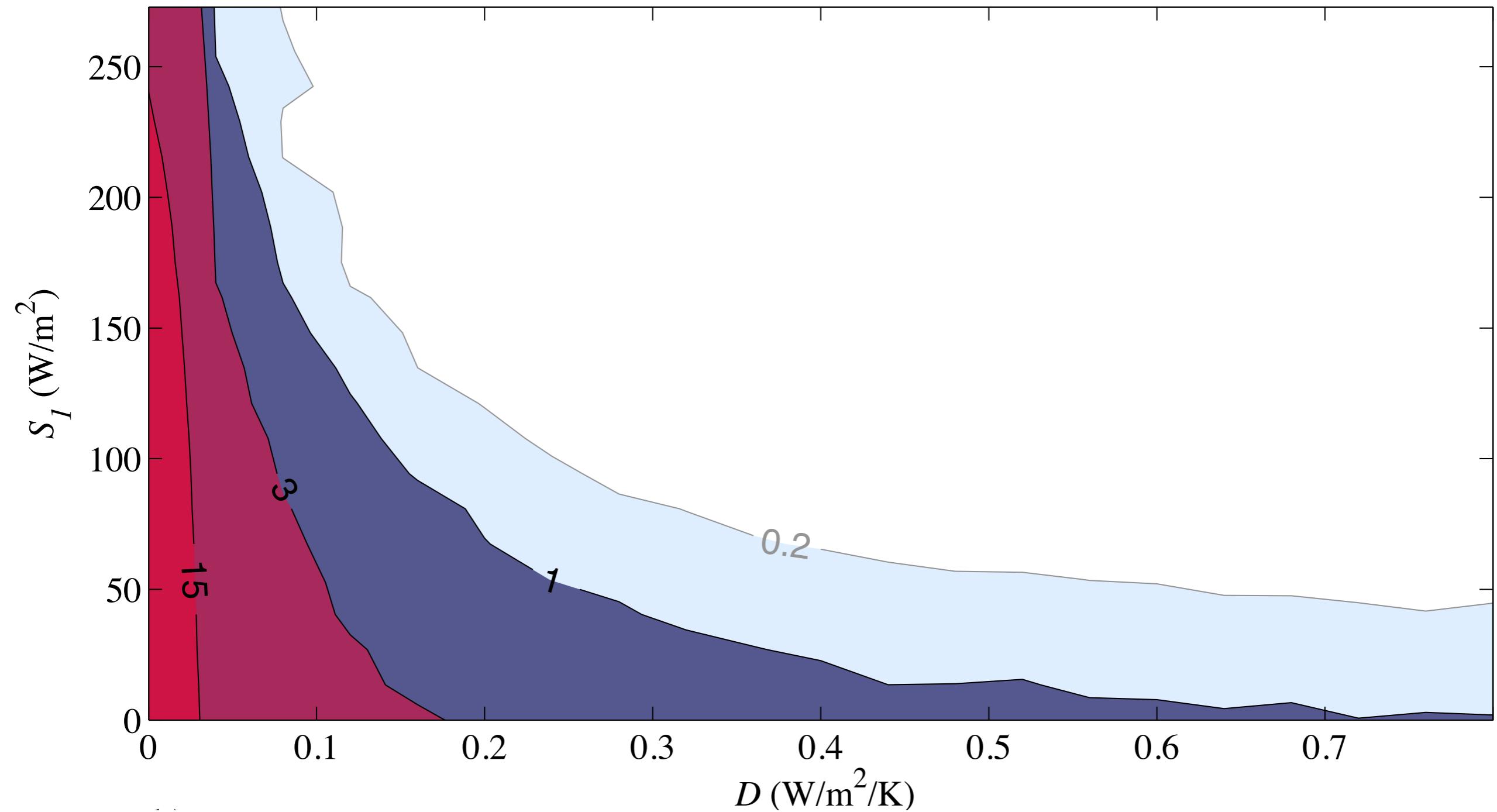
Where do we
lose them?

Explore the parameter space (D, S_1) .

Run Model for

- 21 values in domain $D = [0, D^*]$
 - 21 values in domain $S_1 = [0, S_1^*]$
- } 441 data points in (D, S_1) space

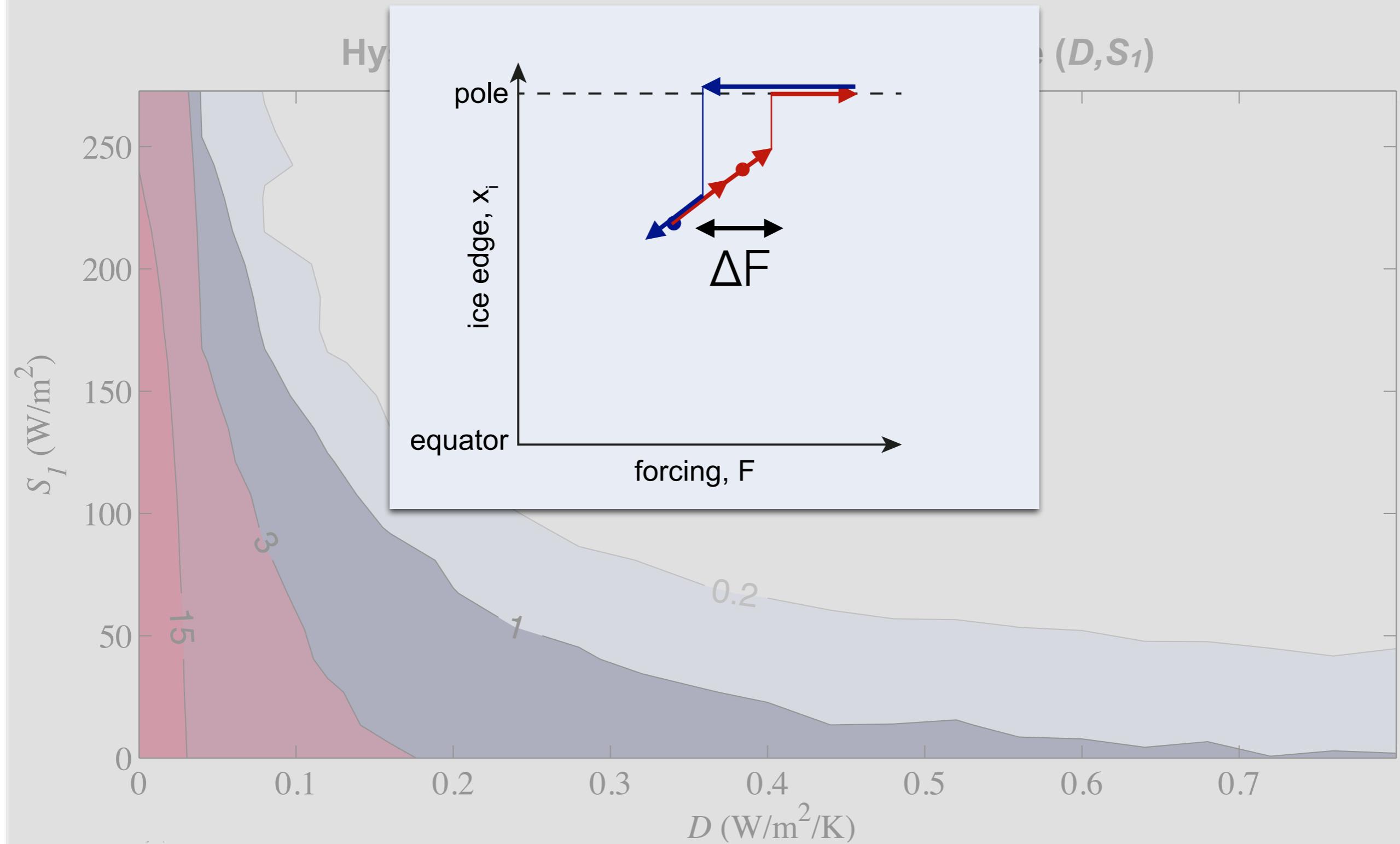
Hysteresis Width, ΔF in parameter space (D, S_1)



Explore the parameter space (D, S_1) .

Run Model for

- 21 values in domain $D = [0, D^*]$
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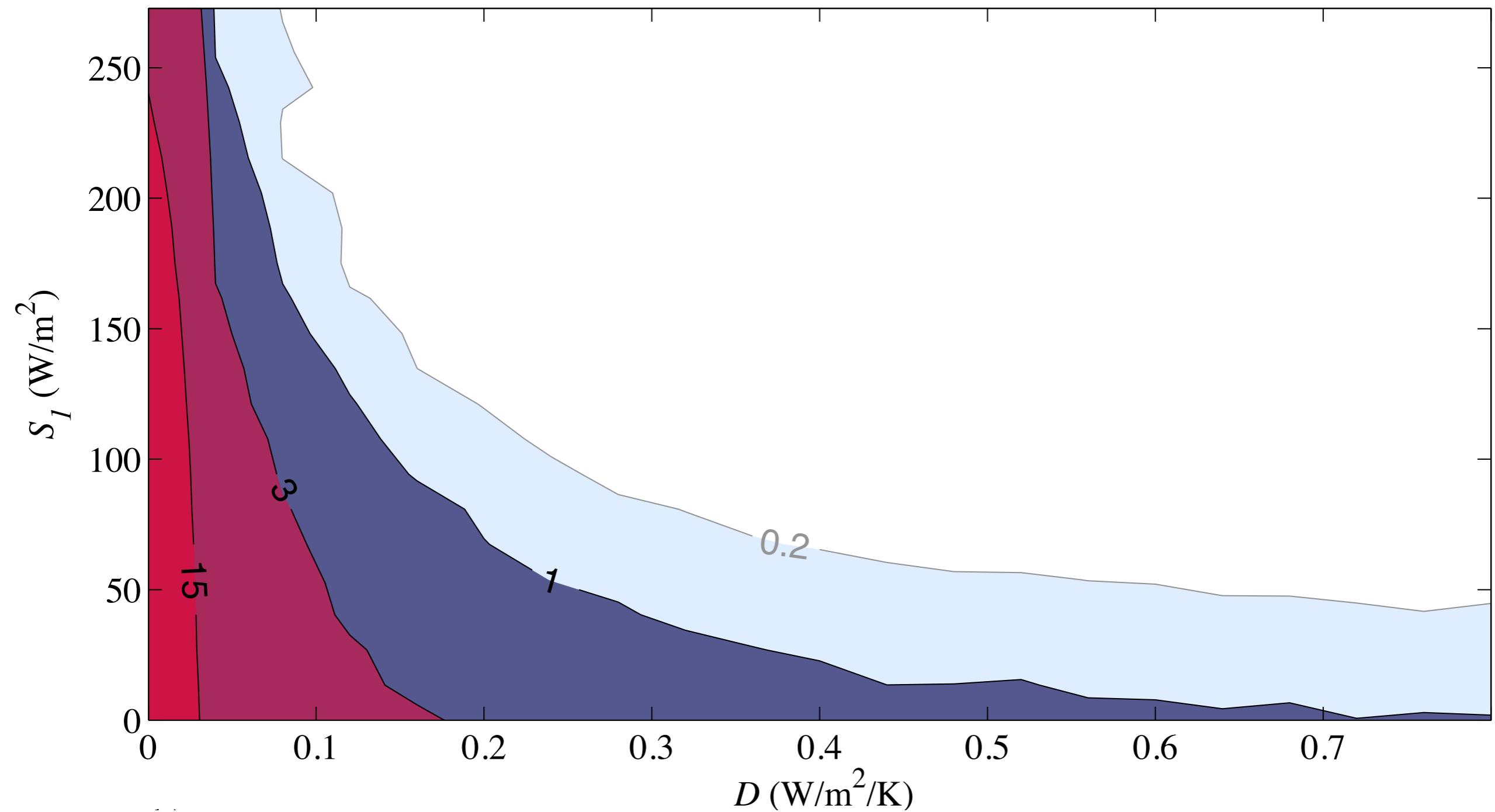


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Hysteresis Width, ΔF in parameter space (D, S_1)

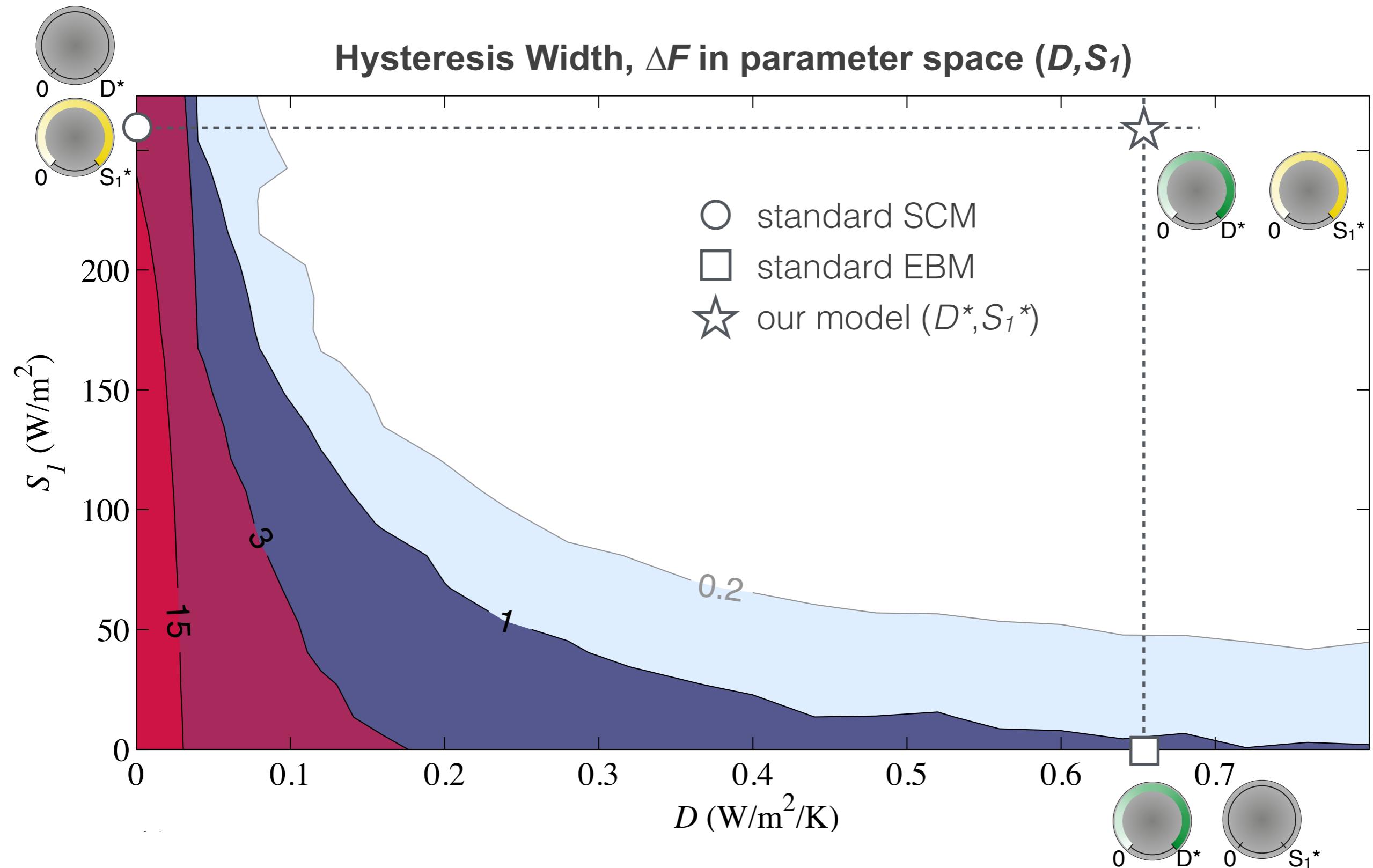


Explore the parameter space (D, S_1).

Run Model for

- 21 values in domain $D = [0, D^*]$
 - 21 values in domain $S_1 = [0, S_1^*]$

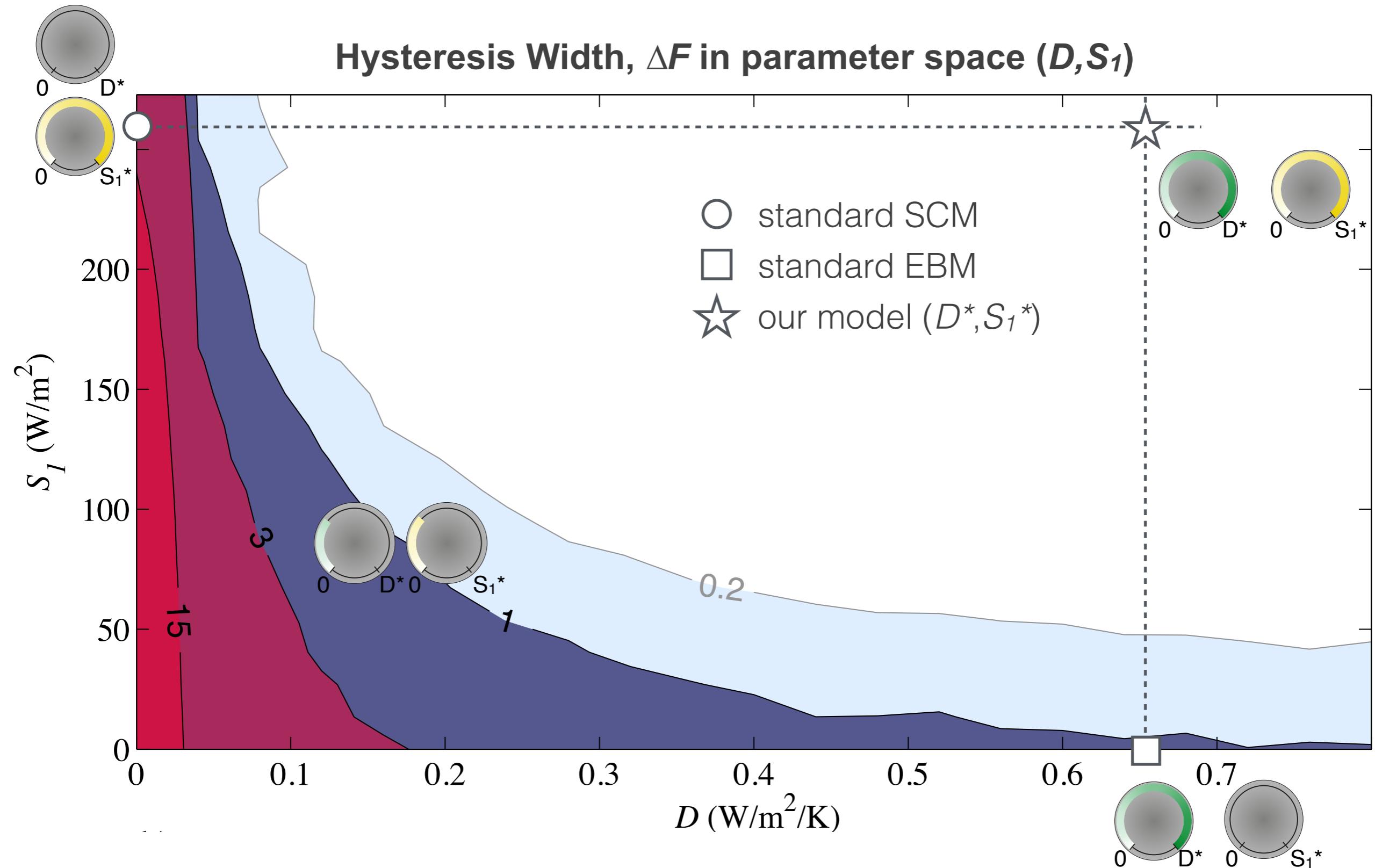
} 441 data points in (D, S_1) space



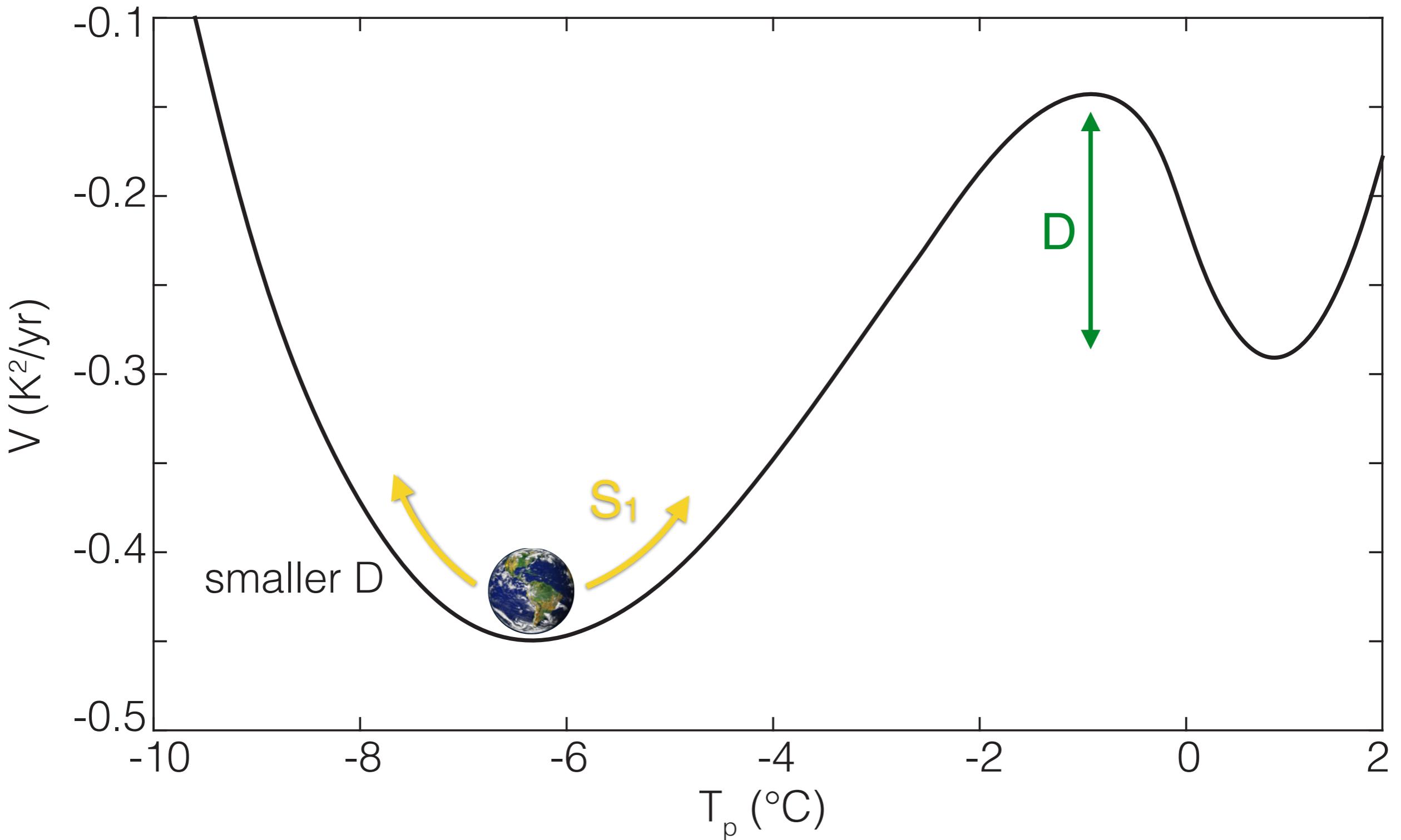
Explore the parameter space (D, S_1) .

Run Model for

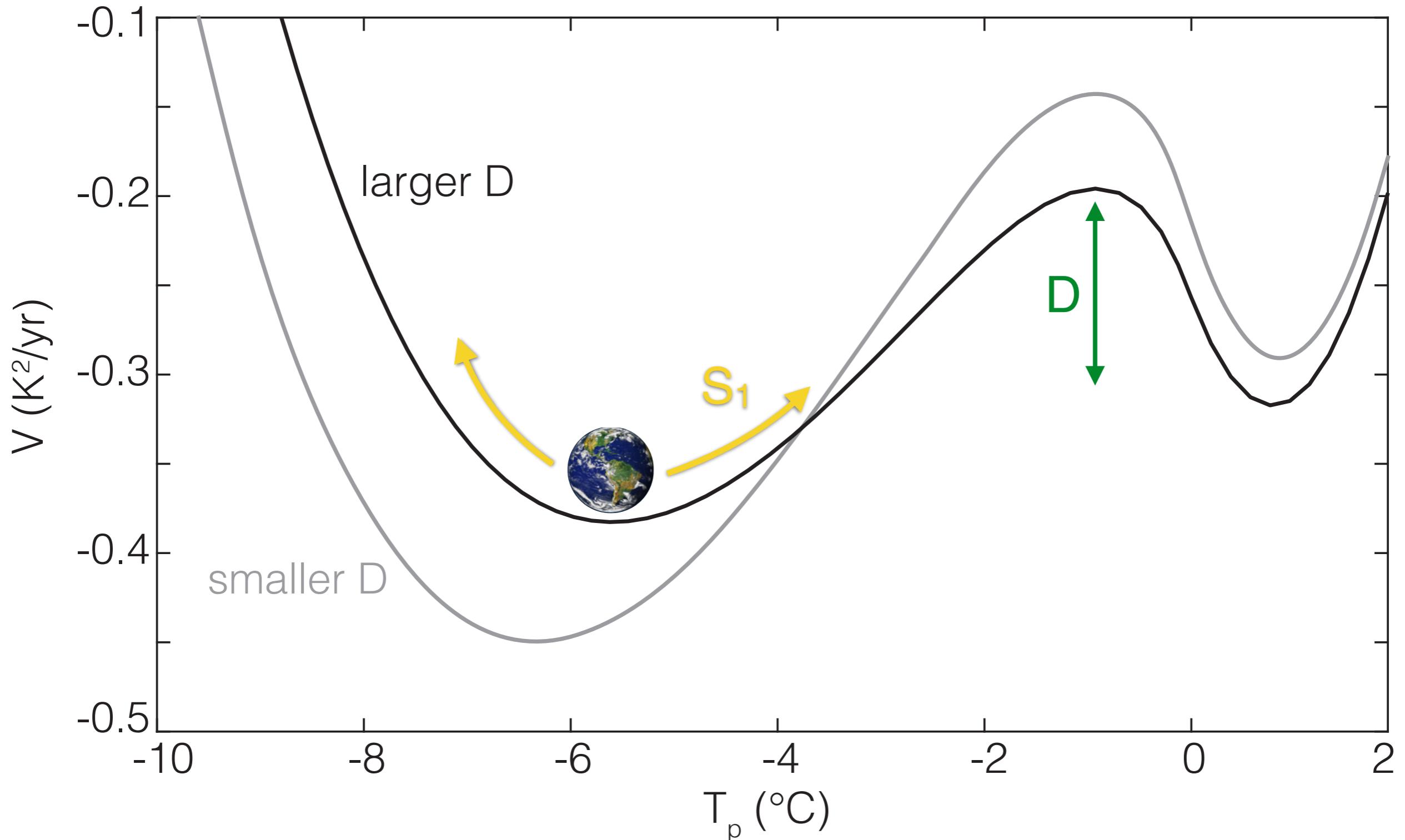
- 21 values in domain $D = [0, D^*]$
 - 21 values in domain $S_1 = [0, S_1^*]$
- } 441 data points in (D, S_1) space

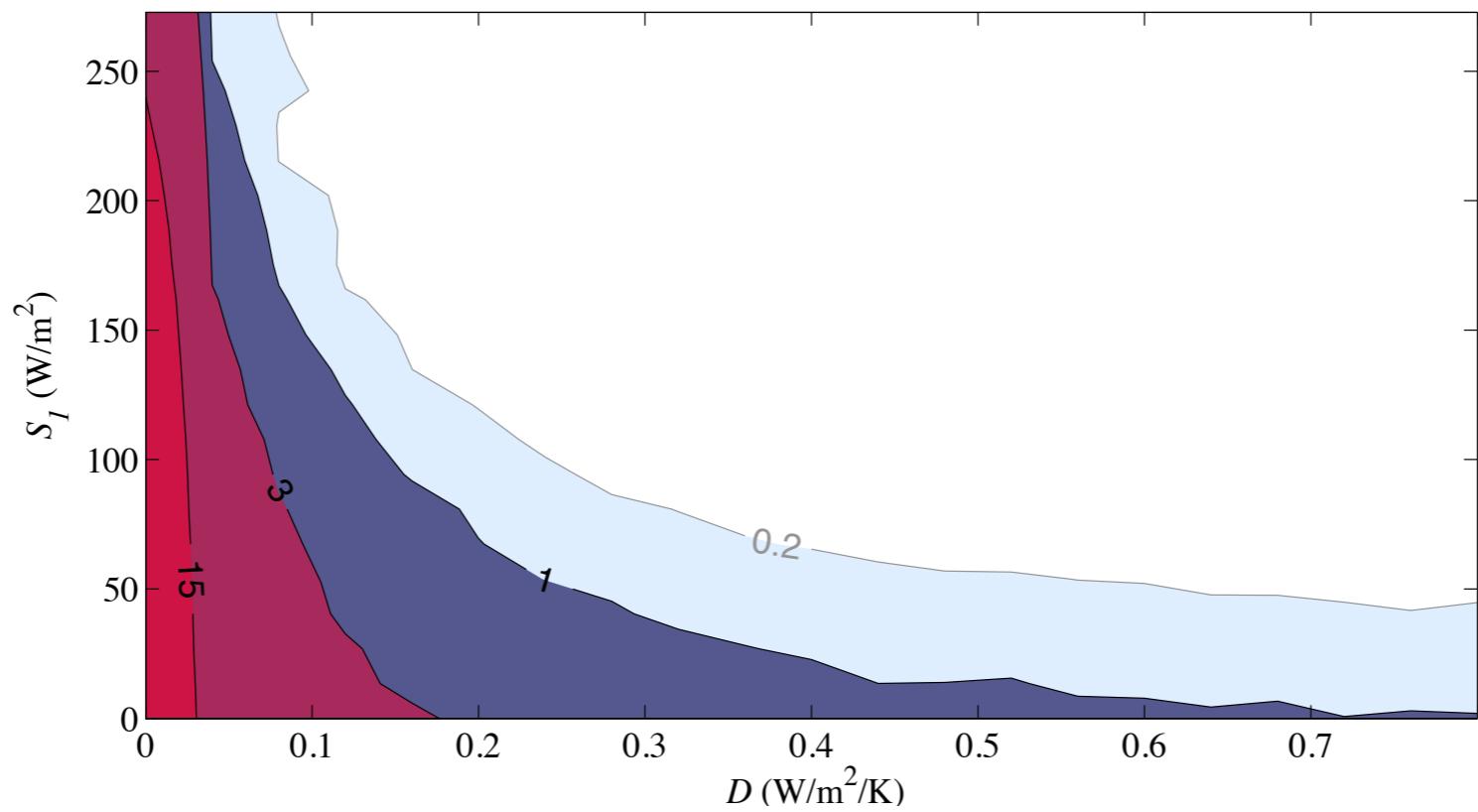


Stabilizing Effects of Spatial and Temporal Variations

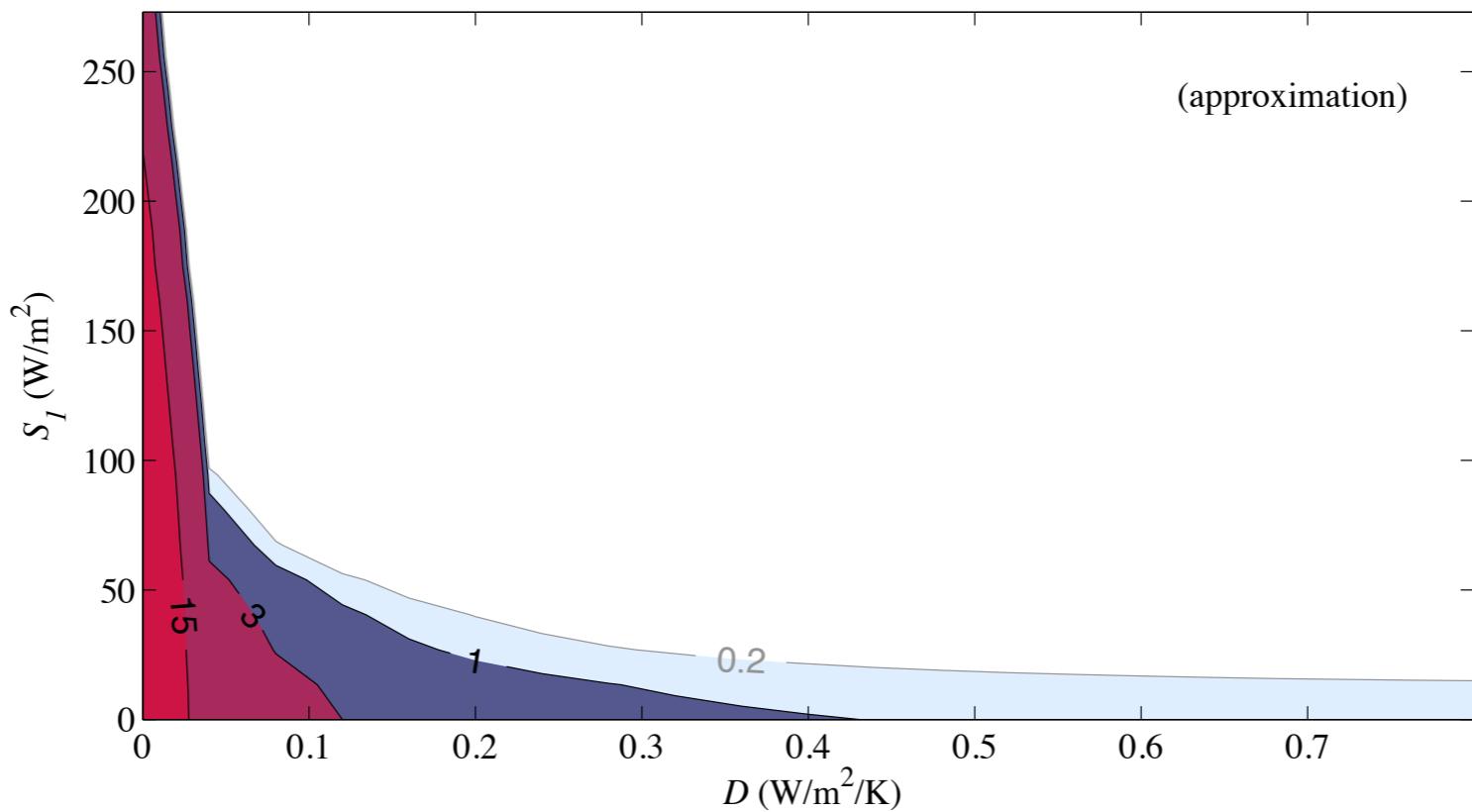
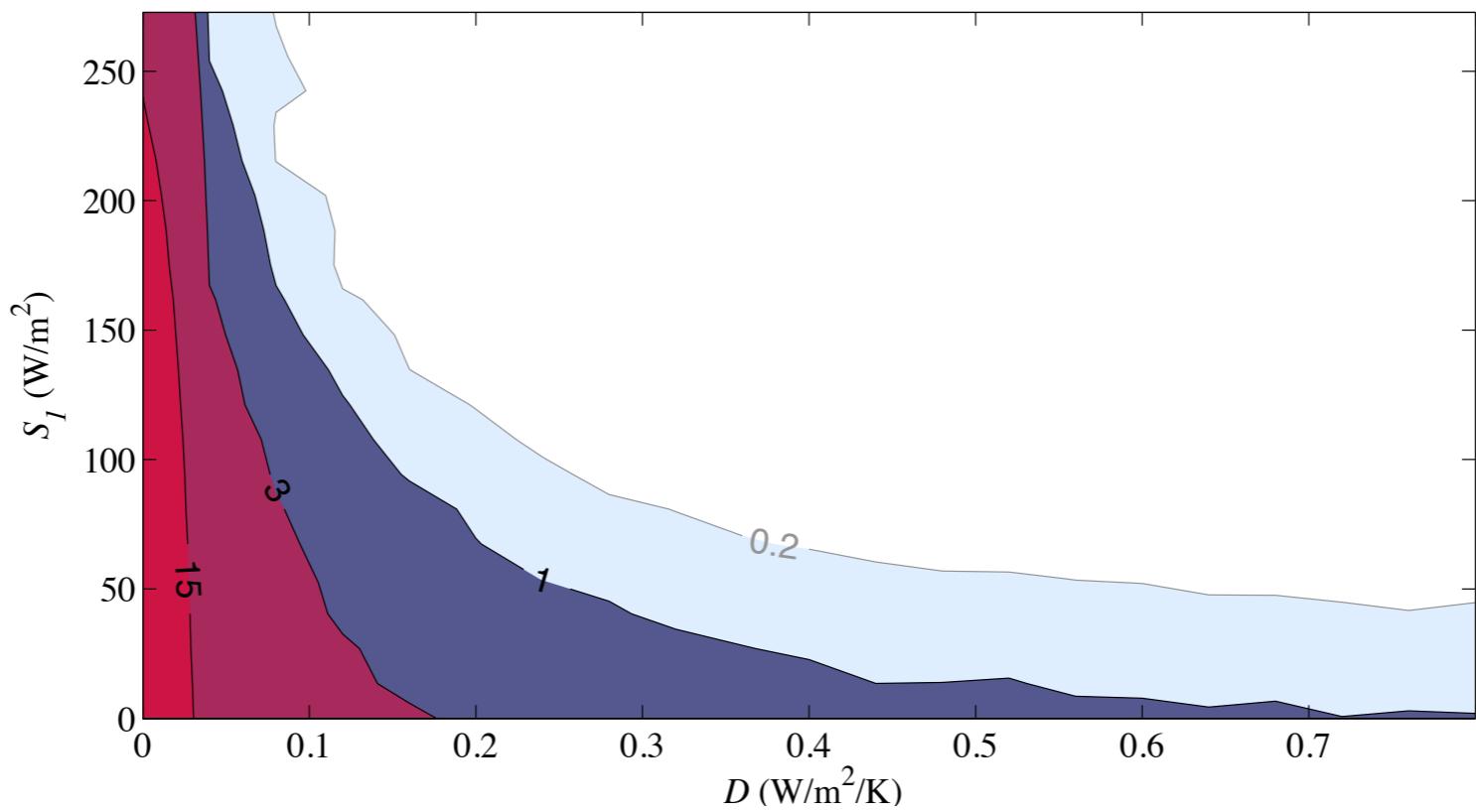


Stabilizing Effects of Spatial and Temporal Variations





SCM EBM



$$\Delta F = \frac{\Delta F(D=0, S_1)}{\text{SCM}} + \frac{\Delta F(D, S_1=0)}{\text{EBM}}$$

Conclusions

Why do low and high order
models disagree?

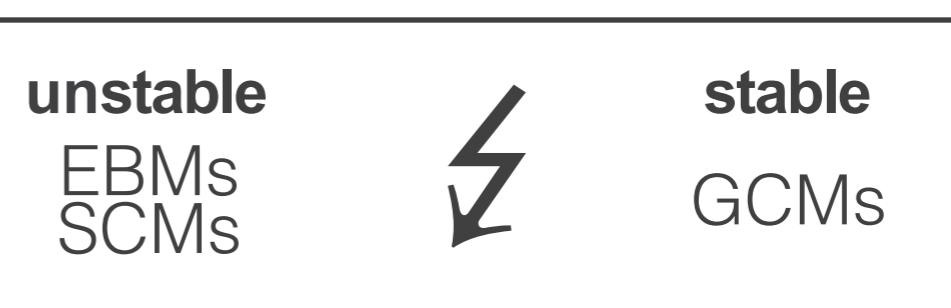
unstable
EBMs
SCMs



stable
GCMs

Conclusions

Why do low and high order models disagree?



EBMs & SCMs are complementary

	spatial variations	seasonal variations
EBMs	✓	✗
SCMs	✗	✓
Our Model	✓	✓

Conclusions

Why do low and high order models disagree?

unstable
EBMs
SCMs

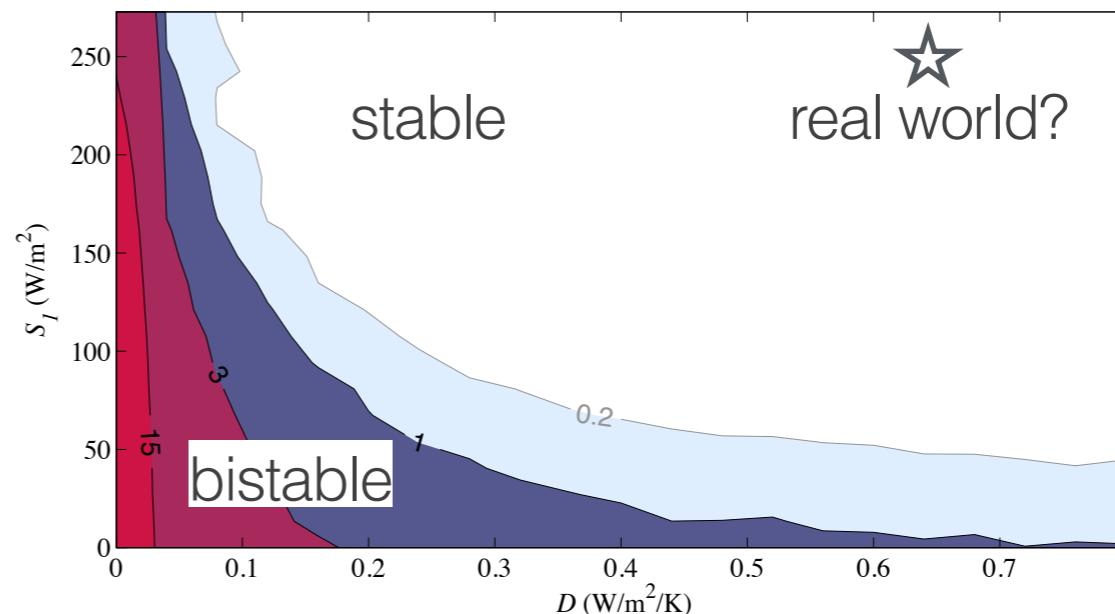
stable
GCMs

EBMs & SCMs are complementary

	spatial variations	seasonal variations
EBMs	✓	✗
SCMs	✗	✓
Our Model	✓	✓

Both spatial and seasonal variations have a stabilizing effect.

A rather simple system with full albedo feedback, that shows no sign of instability.

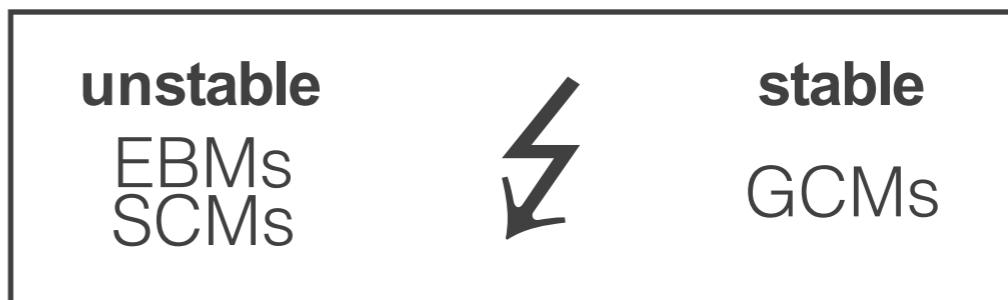


Conclusions

Why do low and high order models disagree?

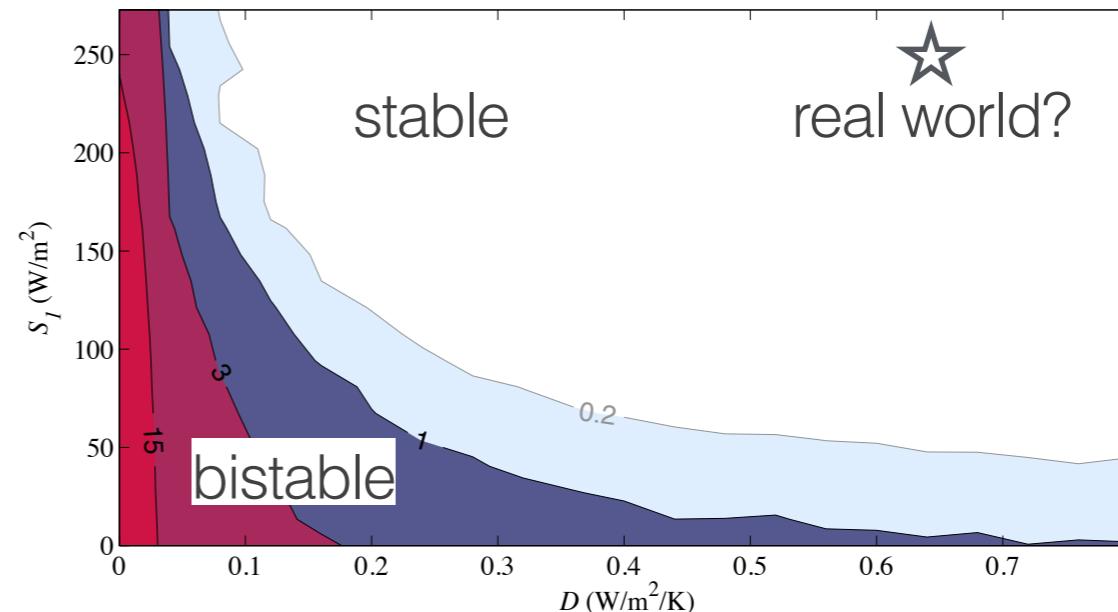
EBMs & SCMs are complementary

A rather simple system with full albedo feedback, that shows no sign of instability.



	spatial variations	seasonal variations
EBMs	✓	✗
SCMs	✗	✓
Our Model	✓	✓

Both spatial and seasonal variations have a stabilizing effect.



GCMs likely correct in predicting no sea ice tipping point.

Food for thought

How do our findings translate
to other dynamic systems?

unstable sea ice
idealized
models



stable sea ice
GCMs

Food for thought

How do our findings translate
to other dynamic systems?

unstable AMOC

idealized
models

Stommel (1961)



stable AMOC

GCMs

Stouffer et al (2006)

Food for thought

How do our findings translate
to other dynamic systems?

unstable Monsoon

idealized
models

Zickfeld et al (2005)



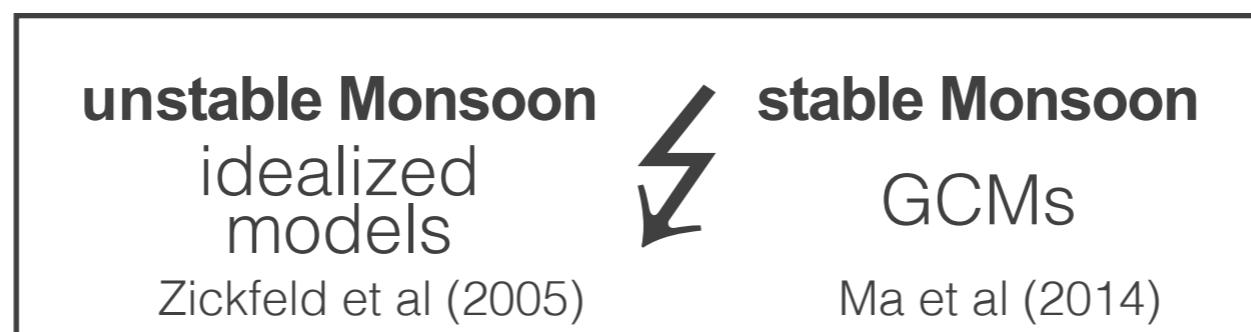
stable Monsoon

GCMs

Ma et al (2014)

Food for thought

How do our findings translate
to other dynamic systems?

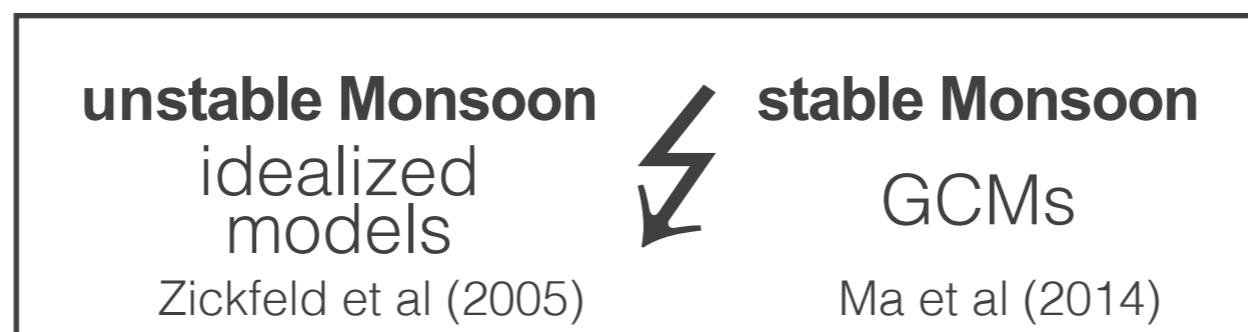


Are there broader implications
for climate models?

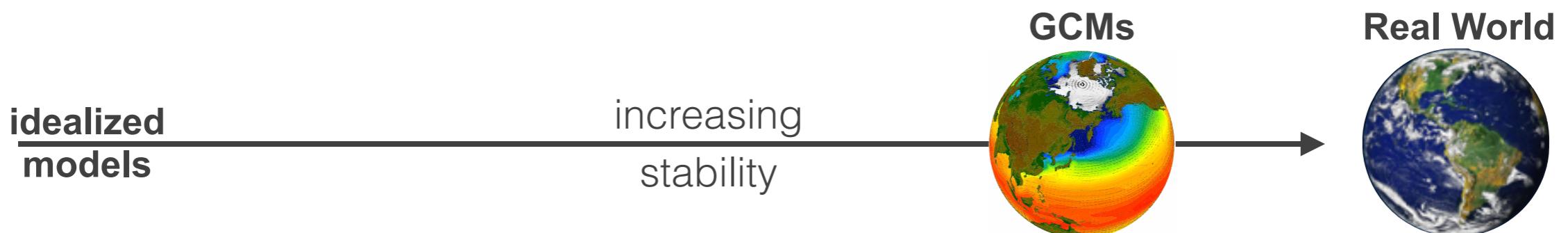


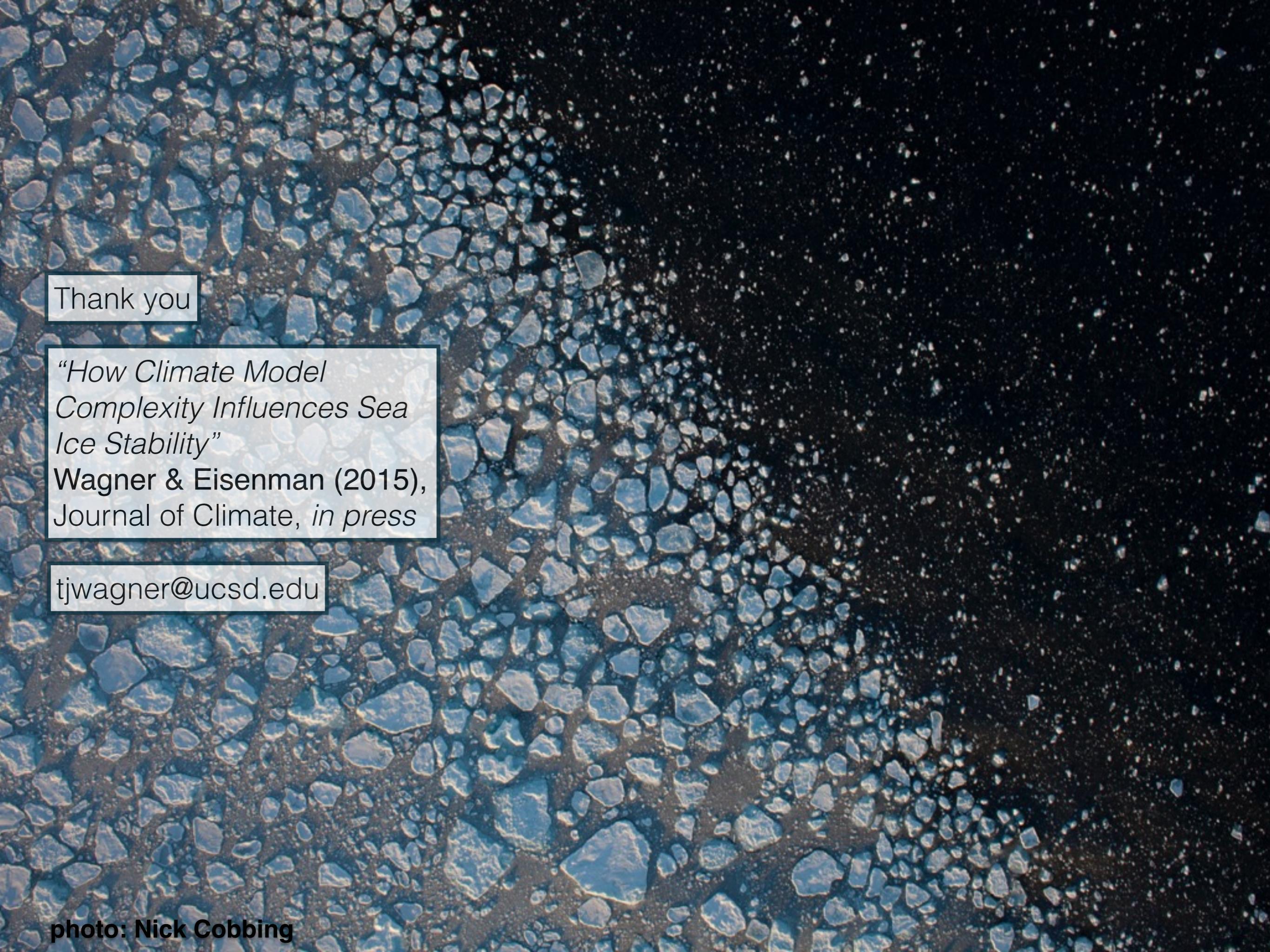
Food for thought

How do our findings translate
to other dynamic systems?



Are there broader implications
for climate models?



The background of the slide is a high-angle aerial photograph of a vast expanse of dark blue ocean covered in numerous small, irregularly shaped white and light blue ice floes. The floes vary in size and density, creating a textured pattern across the dark water.

Thank you

*“How Climate Model
Complexity Influences Sea
Ice Stability”*
Wagner & Eisenman (2015),
Journal of Climate, *in press*

tjwagner@ucsd.edu